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КАФЕДРА КОНСТРУКЦІЇ ЛІТАЛЬНИХ АПАРАТІВ

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«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Конструкція системи запуску малих безпілотних літальних апаратів»

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MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
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«___»___________2022

MASTER DEGREE THESIS
ON SPECIALITY
"AVIATION AND SPACE ROCKET TECHNOLOGY"

Topic: "Design of small fixed unmanned aerial vehicles launch device"

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ЗАВДАННЯ

на виконання кваліфікаційної роботи студента

Лян ЦАЙ

1. Тема роботи «Конструкція системи запуску малих безпілотних літальних апаратів», затверджена наказом ректора від 05 жовтня 2022 року №1861/ст.
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5. Перелік обов’язкового матеріалу: Пояснювальна записка, презентація результатів, розділи, присвячені охороні праці та охороні навколишнього середовища.
6. Календарний план-графік

№	Завдання	Термін виконання	Відмітка про виконання
1	Аналіз стану проблеми	5.10.2022 – 12.10.2022	
2	Проектування системи запуску безпілотного літального апарату	13.10.2022 – 14.10.2022	

3	Аналіз небезпечних зон конструкції системи запуску методом скінченних елементів	15.10.2022 – 28.10.2022	
4	Цифрове складання системи запуску	28.10.2022 – 03.11.2022	
5	Скінченно-елементний аналіз статичного навантажування	03.11.2022 – 07.11.2022	
6	Розробка динамічної моделі системи запуску Бепілотного літального аппарату	07.11.2022 – 12.11.2022	
7	Завершення пояснювальної записки і презентації роботи	12.11.2022 – 15.11.2022	

7. Консультанти з окремих розділів

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"___" ____________ 2022

TASK

for the master degree thesis

CAI Liang

1. Topic "Design of small fixed unmanned aerial vehicles launch device" approved by the Rector's order № 1861/ст from 05 October 2022 year.
2. Period of work execution: from 05 October 2022 year to 30 November 2022 year.
3. Initial data: Characteristics of contemporary unmanned aerial vehicles launch devices.
4. Content: State of the art analysis, UAV launch system design, Analyze of Dangerous Structural Parts of launch system, Digital assembly, Static analysis of the structure, Dynamics model of the UAV launcher.
5. Required material: Explanatory note, Presentation of the results, Chapters devoted to the Labour protection and Environment protection.
6. Thesis schedule

№	Task	Time limits	Done
1	Analysis of Research Technical Background	05.10.2022 – 12.10.2022	
2	UAV launch system design	13.10.2022 – 14.10.2022	
3	Analyze of Dangerous Structural Parts of launch system with Finite Elements Method	15.10.2022 – 28.10.2022	

4	Digital assembly of UAV launch system	28.10.2022 – 3.11.2022	
5	Finite element static analysis of the structure	03.11.2022 – 07.11.2022	
6	Establishment the dynamics model of the UAV launcher	07.11.2022 – 12.11.2022	
7	Completion of the explanatory note and PowerPoint presentation	12.11.2022 – 15.11.2022	

7. Special chapter consultants

Chapter	Consultants	Date, signature	
		Task issued	Task received
Labor protection	PhD, associate professor Katerina KAZHAN		
Environmental protection	PhD, professor Lesya PAVLYUKH		

8. Date: "5" October 2022.

Supervisor of diploma work ________ Mykhailo KARUSKEVYCH

Task for execution is given for ________ Liang CAI

РЕФЕРАТ

Пояснювальна записка дипломної роботи магістра «Конструкція системи запуску малих безпілотних літальних апаратів»

77 с., 56 рис., 16 табл., 37 джерел

Магістерська робота присвячена зльоту 25-кілограмового БПЛА на катапульті для зменшення ваги дрона та збільшення часу польоту.

Результати показують, що для зменшення ваги БПЛА пускова установка БПЛА може відповідати запуску БПЛА.

Реальність дослідження викликана збільшенням часу польоту дрона.

Завдяки цифровому моделюванню, збірці, а потім динамічному моделюванню та статичному аналізу пристрою запуску, кінцевим результатом є те, що пристрій може відповідати вимогам безпечного та надійного запуску БПЛА.

Результати дослідження можуть бути використані в авіаційній промисловості, а також у науково-дослідній діяльності.

Безпілотні літальні апарати, метод скінченних елементів, цифрове складання, динамічна модель, статичний аналіз

ABSTRACT

Master degree thesis "Design of small fixed Unmanned aerial vehicles launch device"

77 p., 56 fig., 16 tables, 37 references

The master thesis deals with the takeoff of a 25kg UAV on a catapult to reduce the weight of the drone and increase the flight time.

The results show that for UAV weight reduction, UAV launcher can well meet UAV launch.

Reality of the research caused by increasing the flight time of the drone.

Through digital modeling, assembly, and then dynamic simulation and static analysis of the launch device, the final result is that the device can meet the safe and reliable launch requirements of the UAV.

Results of the research can be used in aviation industry as well as in research and development activity.

Unmanned aerial vehicles, finite element method, digital assembly, dynamic model, static analysis

ABBREVIATIONS

ICAO – International Civil Aviation Organization;

EASA – European Union Aviation Safety Agency;

UAV - Unmanned Aerial Vehicle;

AUVSI - Association for Unmanned Systems International;

RATO - Rocket-Assisted Take-Off;

FEM - Finite Element Method;

DM - Dynamic Model

Content

Introduction

Diploma work dealing with unstable acceleration of small fixed-wing drones during launch

The problem is practical, because launches are critical to unmanned aerial systems.

The research consists of a corresponding design study for a 25kg UAV.

The disadvantages of the past development are that the problems of acceleration stability and low cost of the launch system during the launch of small fixed-wing UAVs have not yet been solved.

In order to solve the problem of the UAV launch device proposed in this work

The work objectives and main tasks are

1. To design the entire launch plan.
2. To build the individual parts of the launch system.
3. To assemble the launch system digitally.
4. To analyze Dangerous Structural Parts of launch system with Finite Element Static Analysis.
5. To do dynamic simulation of the launch process.

The method used is to digitally model the entire launcher, then perform a dynamic analysis, and perform a static analysis of the device, and finally obtain a launcher that meets the requirements.

The novelty of the diploma work is the new launch device, which maintains a stable acceleration during the launch process and quickly launches the drone.

The work can be implemented in the fields of aviation, research and development, education, etc.

PART 1. STATE OF ART

1.1 Research Technical Background

Unmanned aerial vehicles (UAVs) are unmanned aerial vehicles, without pilots or passengers, that can be remotely piloted or pre-programmed to fly autonomously [1]. UAVs have developed rapidly in recent years, and are favored by the military and borders for their concealment, survivability, low cost, and no fear of casualties. It is widely used in tasks such as providing intelligence, surveillance, target acquisition and reconnaissance [2]. With the rapid development of unmanned aerial vehicle equipment technology, new quality unmanned aerial vehicle systems continue to emerge, and the application of emerging technologies such as artificial intelligence has continuously improved the ability of manned and unmanned coordination. It is an important component to reshape the future air combat mode [3]. In 2020, the U.S. MQ-9 "Reaper" UAV launched an air strike near Baghdad International Airport in Iraq, killing Major General Qasem Soleimani of the Iranian Islamic Revolutionary Guard Corps. UAVs are extremely important in the modern battlefield. tactical and strategic implications.

UAVs are widely used in the military, and with the development of UAVs in recent years, there are more and more application scenarios in the civilian public domain. According to a survey by the Association for Unmanned Systems International (AUVSI) on UAV civilian applications in the United States, the top three applications in the UAV industry are construction, infrastructure, and agriculture [4]. This also shows that UAVs are more and more widely used in various fields, and they take on increasingly critical tasks.

Small fixed-wing UAVs refer to UAVs with a body weight in the range of 20 kg to 150 kg [5]. In recent years, UAVs have developed rapidly in the field of military defense and civilian use. In the field of military and national defense, it is favored by the military and borders for its concealment ability, survivability, low cost, and no fear of casualties [6-7]. Compared with manned aircraft, UAVs have the following significant advantages: when dealing with long-term boring tasks, UAVs can maintain the best state for a long time compared to people; when carrying out tasks with high risk factors. The cost of failure is small; the use of UAVs in polluted areas can avoid the danger of casualties [7].

In the civilian field, small UAVs have developed rapidly in recent years and are widely used in various scenarios. For example, surveying and mapping of infrastructure and complex terrain, monitoring of buildings, forest fire prevention and firefighting, agricultural plant protection, security inspection, monitoring of marine resources, etc. [7-8].

The application scenarios of small UAVs are gradually increasing, and the equipment carried by them is becoming more and more precise, so it is very important for the use of UAVs to achieve safe launch [9]. Aiming at the working conditions and characteristics of 25KG UAV, this project designs a launch device that can meet the requirements of fast and stable launch of UAV.

In addition, for the launch of small fixed-wing UAVs, a new type of launch device for small fixed-wing UAVs is innovatively designed and designed from the perspective of structure and principle. The launch device meets the launch speed of the UAV to reach 25m/s. Moreover, the conditions of simple structure, stable emission and low cost are satisfied.

1.2 Status of UAV launches in the world

UAVs choose different launch methods according to the nature and occasion of work, take-off weight, power source, and take-off overload. UAV launch is mainly divided into the following methods: runway take-off, catapult take-off, hand throw take-off, rocket-assisted take-off (RATO) launch, aerial launch, vertical take-off.

（1）Runway Take-off

Runway take-off is divided into landing gear take-off, Vehicle take-off and take-off from the surface of water. The landing gear take-off is a way for the UAV to run on the runway with the thrust of the engine to complete the take-off. Vehicle take-off and take-off from the surface of water is that the UAV relies on the car and ship take-off device to obtain the take-off speed to complete the take-off [10]. The difficulty of landing gear take-off lies in the structural design of the landing gear, but less equipment is required for take-off. In the process of landing gear take-off, the overload is small, but the requirements for the field are relatively high. For example, the US light reconnaissance UAV RQ-7 Shadow has a maximum take-off weight of 170kg; the RQ-2 (Fig.1.1) Pioneer unmanned reconnaissance aircraft has a maximum take-off weight of 205kg. Israel's "Searcher MKII" UAV (Fig.1.2) with a maximum take-off weight of 426kg.

Fig.1.1 - RQ-2 Pioneer

Fig.1.2 - Searcher MKII

（2）Rocket-Assisted Take-off

Rocket-assisted take-off is a launch method in which the UAV obtains a certain speed and altitude in a short period of time by relying on the thrust of the booster rocket during launch [11]. The rocket-assisted take-off is less restricted by the site and has high maneuverability. However, the launch process involves the transportation and storage of pyrotechnics, and a large acousto-optic smoke signal will be generated during the launch process [13]. For example, China ASN-209 (Fig.1.3) has a maximum take-off weight of 320kg, and ASN-215 has a maximum take-off weight of 220kg. Both are launched with a single-shot rocket under the fuselage. The American BQM-74E "Chukar" (Fig.1.4) and Italian Scrab III (Fig.1.5) have a maximum take-off weight of 140kg. The man-machine is launched with a twin-engine rocket booster.

Fig.1.3 - ASN-209

Fig.1.4 - American "Chukar"

Fig.1.5 - Italy Scrab III

（3）Hand-throwing Take-off

The UAV hand-throwing is suitable for UAVs with small size and mass. It mainly undertakes tactical reconnaissance tasks and is used to provide intelligence support for the combat operations of individual soldiers or small teams. The operator holds the UAV and throws the UAV after controlling the direction and strength [13]. Such as the RQ-11Raven UAV (Fig.1.6) in the United States, with a maximum take-off weight of 1.9kg, and the RQ-14 (Fig.1.7), Dragon Eye UAV, with a maximum take-off weight of 2.49kg

Fig.1.6 - RQ-11Raven

Fig.1.7 - RQ-14

（4）Aerial Release

Aerial release means that the UAV is dropped in the air by a transport aircraft or other carrier aircraft, and the carrier aircraft is used to achieve the altitude and speed required for the autonomous flight of the UAV. Aerial launch has less requirements on the take-off auxiliary equipment of UAVs, and higher requirements on the carrier aircraft and its take-off site [11-13]. On March 26, 2021, the U.S. military used the XQ-58A "Valkyrie" (Fig.1.8) stealth UAV to complete the verification of the air-launched ALTIUS-600 UAV, achieving a new breakthrough in the UAV air-launched UAV. With the ALTIUS-600 UAS (Fig.1.9) can be integrated and launched from military aircraft such as the C-130A, P-3 Orion, AC-130J and UH-60(Fig.1.10). It can also be launched from civilian aircraft, ground vehicles and sea-based platforms.

Fig.1.8-XQ-58A"Valkyrie"

Fig.1.9-ALTIUS-600

Fig.1.10 - UH-60

（5）Vertically Take-off

UAVs that can take off vertically have a special structure, with both rotors and fixed wings. The vertical take-off and landing UAV combines the advantages of both, but the structure is more complex, and the requirements for materials and flight control systems are relatively high [14-15]. For example, the "Eagle Eye" UAV developed by Bell Corporation of the United States for maritime patrols, and CH-10 Rainbow-10 Tilt-Rotor VTOL Shipboard Reconnaissance Strike Drone (Fig.1.12) developed by the Eleventh Academy of Aerospace of China.

Fig.1.11 - "Eagle Eye"

Fig.1.12 - CH-10 Rainbow-10

（5）Ejection Take-off

Ejection take-off can be divided into liquid/gas ejection, elastic ejection, electromagnetic ejection, and gas ejection according to the different power sources of the ejection device. The principle of catapult take-off is to use gas-liquid energy, elastic potential energy stored in elastic ropes, electromagnetic energy, gas energy and other energy sources as the driving force for the take-off of the UAV, and convert the energy into kinetic energy for the take-off of the UAV through a series of devices such as guide rails. The liquid/gas ejection uses gas-hydraulic energy as the power source for the take-off of the UAV, which has good applicability and relatively mature technology [16]. The elastic ejection uses the elastic potential energy stored by elastic elements such as springs and bungee ropes as the kinetic energy for the take-off of the UAV. It has a simple structure and is easy to operate. Electromagnetic ejection is to place the energized armature of the UAV in the electromagnetic field generated by the linear motor, and use the electromagnetic force to make it complete the accelerated launch process. [18-19]. Gas ejection refers to the process in which the UAV uses the thrust generated by the combustion of gunpowder to accelerate the launch in various artillery barrels [13-15]. For example, the ScanEagle UAV (Fig.1.13) from the United States has a maximum take-off weight of 20kg; the

German Luna UAV (Fig.1.14) has a maximum take-off weight of 37kg; the French Sperwer B (Fig.1.15) has a maximum take-off weight of 100kg; Israel's Harpy UAV (Fig.1.16) has a maximum take-off weight of 135kg.

Fig.1.13 - "Scan Eagle"

Fig.1.14 - German " Luna "

Fig.1.15 - Sperwer B Ejection

Fig.1.16 - "Harpy" Gas ejection

1.3 Key Point and Difficulties of Research

In the existing UAV launch system, the launch system is not a stable output due to its dynamic characteristics, such as the elastic coefficient of elastic, so there is often a problem of unstable acceleration during the launch process. The hydraulic launching device is complex, heavy, and expensive. The rocket-assisted launch will involve the storage and transportation of pyrotechnics, which requires high safety and high cost.

In the upcoming study, a UAV launch system will be designed. The launch system designed for the 25KG UAV this time enables the UAV to quickly reach the take-off speed through external power. The external power of the motor propeller is used, and the whole composed of the cradle and the UAV is driven by the power generated by the motor propeller. Compared with the existing solution, the acceleration generated by the power generated by the motor propeller during the launch process is relatively stable.

In order to ensure that the launch system can successfully launch the 25KG UAV, and the UAV has a speed of 25m/s at the end of the launcher track. It is necessary to obtain results that can meet the target in terms of the launcher structure and launch dynamics. Therefore, it is necessary to first carry out digital modeling and assembly of the launch system to ensure the rationality of the structure, and to carry out finite element static analysis and digital assembly of the structure of the launcher. The weight of the aircraft, the selected power, the friction of the track, and the changes in the lift and drag of the UAV during the launch process are modeled dynamically, and the simulation results are analyzed to ensure the smooth launch of the 25KG UAV.

Conclusion to part 1. Aim and objectives of the research.

Analysis of the current situation with research and development in the field of Unmanned aerial vehicles has shown that the problems such as stable acceleration during launch and low cost of launch system are still unsolved. For the improvement of the Unmanned aerial vehicles launch characteristics the following aim has been formulated:

For a 25kg UAV, the launch process can be achieved stable, the speed of the UAV at the end of the launch track reaches 25m/s, the maximum overload that the UAV bears during the whole process does not exceed 10g, and the length of the launch track does not exceed 11m.

To achieve this, aim the following task have been formulated and solved:

1. To design the entire launch plan.
2. To build the individual parts of the launch system.
3. To assemble the launch system digitally.
4. To analyze Dangerous Structural Parts of launch system with Finite Element Static Analysis.
5. To do dynamic simulation of the launch process.

PART 2. UAV LAUNCH SYSTEM DESIGN

2.1 Introduction to UAV Launching System

The UAV launch device is an important part of the UAV system. The purpose of designing the UAV launch system is to enable the UAV to obtain the initial speed that can take off in a short distance and time, to obtain the lift required for take-off. At this stage, the take-off methods of UAVs mainly include runway take-off, hand-throwing take-off, rocket-assisted take-off, catapult take-off, aerial launch, and vertical take-off. The principle of catapult take-off is to use gas-liquid energy, elastic potential energy stored in elastic rope, electromagnetic energy, gas energy and other energy sources as the driving force for the take-off of the drone, and convert the energy into kinetic energy for the take-off of the drone through a series of devices such as guide rails [20]. The catapult take-off is to accelerate the UAV on the track to a certain range and then take off. The catapult take-off UAV has high launch efficiency, short equipment time, and small site restrictions. It can achieve rapid deployment, rapid movement, and continuous launch.

In this part, the UAV launch device is designed for the 25kg UAV, the advantages and disadvantages of each launch device are integrated, and the catapult device is finally selected. The ejection device uses the motor propeller as the power device for the UAV to eject and take off.

2.2 UAV launch technical requirements

The main technical parameters of the UAV are shown in Table 2-1:

Table 2.1 - Key parameters of the launch system

Name	Parameter
MTOW	25kg
Take-off speed	25m/s
Cradle motor	DUALSKY GA8000S
Propeller	28x12

The goal is mainly aimed at the launcher that needs to be designed for 25kg UAVs and needs to meet the following conditions:

1. The launch end speed needs to reach 20m/s for the drone to take off normally, so the design speed is 25m/s.

2. The power unit should provide sufficient thrust.

3. The launcher is as simple as possible in structure and assembly.

4. The strength and stiffness of the launcher need to meet the requirements to ensure the reliability and safety of the launcher.

5. During the launch process, the acceleration overload of the drone should not be too large, and the launch distance should not be too long.

6. The structure of the cradle is as simple as possible and the weight is as light as possible.

2.3 UAV launch system scheme design

The UAV launch system can accelerate the UAV to a speed that can take off smoothly in a short time. The UAV launch system consists of several parts. Moreover, the cost should be reduced as much as possible on the premise of meeting the design requirements, and the structure is simple, durable, and long in-service life.

The UAV launch device includes three major parts: the main launch frame, the cradle, and the damping device. The launch frame is the base of the entire launch system, supporting the UAV to run and take off on the track; It is responsible for transmitting the power output from the power unit to the UAV, and finally accelerates the UAV to the specified speed. It is also the link on the structural connection, and is responsible for supporting the UAV to slide on the launcher track and keep it free of charge. The attitude of the man-machine, to take off smoothly. The damping device is located at the end of the launch track, mainly to absorb the impact energy of the cradle and prevent the high-speed impact from causing damage to the cradle structure and other parts.

In order to meet the smooth launch of the UAV, it is necessary to meet certain requirements in terms of power firstly. The power used by the UAV launch device consists of many types, including hydraulic/pneumatic, electromagnetic, elastic, and rocket booster. The power of the launcher adopts the motor propeller, and the thrust generated by it enables the cradle to carry the UAV to quickly reach the specified take-off speed. The thrust generated by the power unit during the selection should enable the UAV to take off smoothly within a limited distance of the launch track, but also ensure that the overload of the UAV during the acceleration process cannot be too large, in order to avoid damage to the structure of the UAV and its internal functional loads.

In addition to power, during the launch process, the structure also needs to meet the launch requirements, including that the propeller part of the power unit cannot interfere with the position of the UAV, and the attitude of the UAV will change when it takes off. The dynamic position of the man-machine and the support arm of the cradle cannot be launched and interfered, which ultimately ensures that the UAV can take off smoothly at a certain angle of attack.

Due to the complex structure of the launch system, when designing the launch system for the UAV, it is necessary to start from the UAV according to a certain design sequence and logic, and design other parts according to the "contact" principle, as shown in the following Fig.2.1:

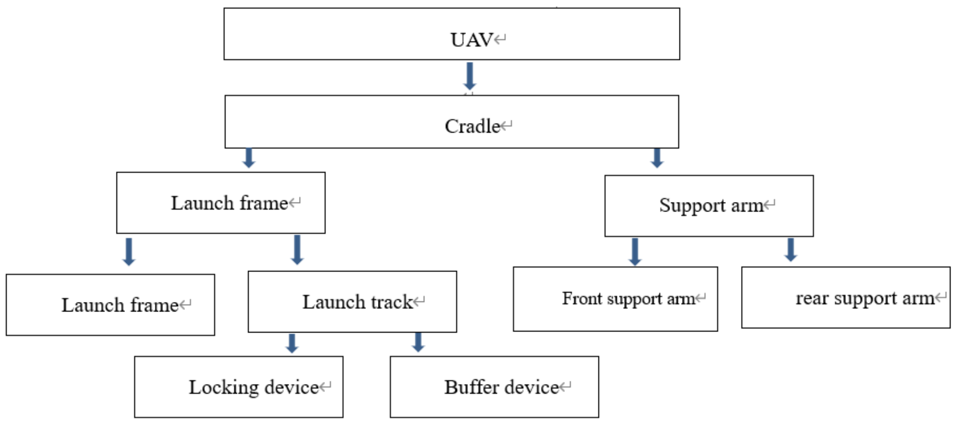

Fig.2.1 - Launch System Design Logic

According to the design logic given in the design above, firstly design the cradle in contact with the drone, including the size and structure of the support arm, and secondly design the structure of the launcher that in contact with the cradle, including the connection and size between the cradle and the launcher. Finally, carry out the structural design of the support of the launch frame, the locking device, and the buffer device at both ends.

Therefore, the launch system can be initially determined as three parts: launch frame, cradle, and buffer system, each of which can have several main structures. The structural relationship between each part is shown in the following Fig.2.2:

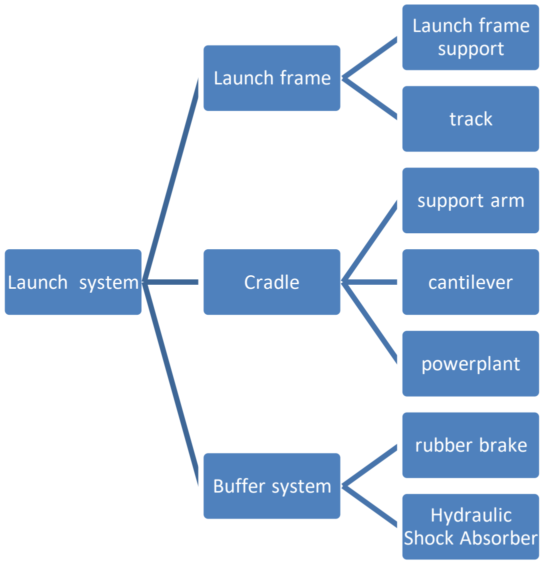

Fig.2.2 - UAV launch system structure relationship

On the premise of meeting the design requirements, according to the structural relationship diagram of the UAV launch system, each part is designed in detail. The following three sections respectively carry out the detailed parameter design of the launcher, the cradle, and the buffer system.

2.3.1 The frame of launcher

The frame of launcher is the base of the entire launch system and provides a runway for the cradle. The whole composed of the cradle and the drone needs to complete the acceleration, deceleration, and buffering process on the launcher. The launch frame consists of a launch track and a frame. The launch track consists of a rectangular section tube and a plane with two V-shaped tracks. The frame is responsible for supporting and connecting the launch track. In addition, the end of the launch track is equipped with a buffer device, so the size and strength of the launch frame and various parts and parts must meet the requirements of UAV launch.

The launch frame of the launching device is welded by two C-shaped steels (Fig.2.3) back-to-back, and the track of the cradle pulley is welded by 40mm angle steel. In order to increase the strength, steel plates are welded on the inner side and the upper and lower sides of the two C-shaped steels respectively.

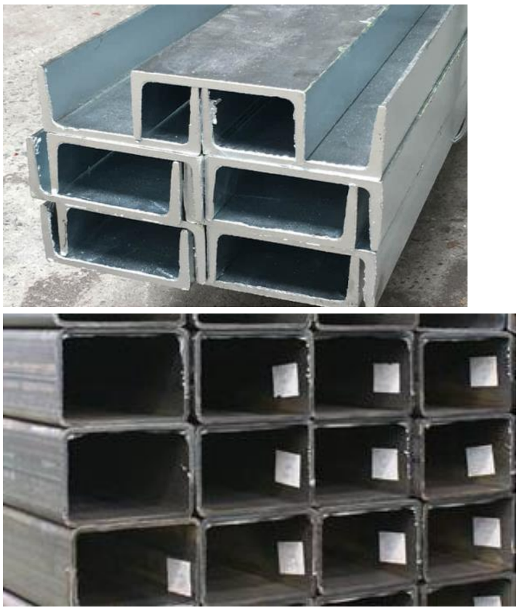

Fig.2.3 - Launcher steel

The support device of the launcher is mainly consisting of two parts. The first part is located at the end of the launch track and is used to stabilize the launcher and provide support. The second part is the support structure composed of wheels and trusses (Fig.2.5), which can provide most of the support for the launcher, and the wheels also greatly facilitate the adjustment of the position of the launcher. The truss is welded by angle steel and C-shaped steel, and the support device and the launcher are connected by bolts. The structure is shown in Fig. 2.4:

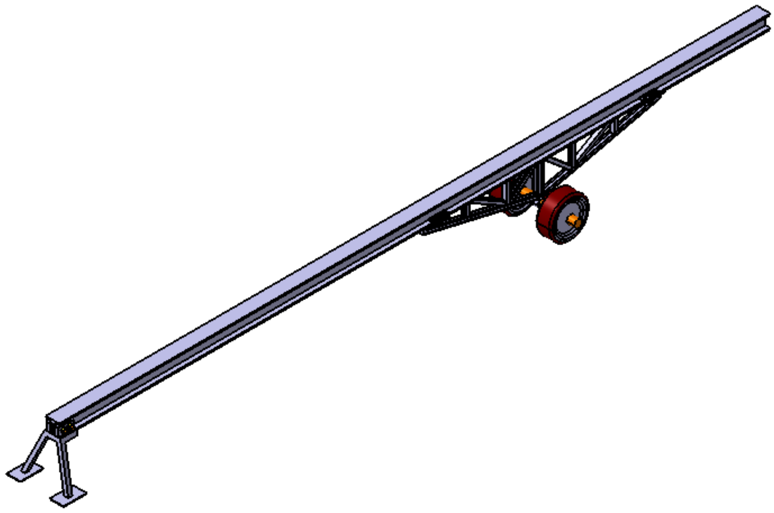

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Fig.2.4 - Launcher Assembly

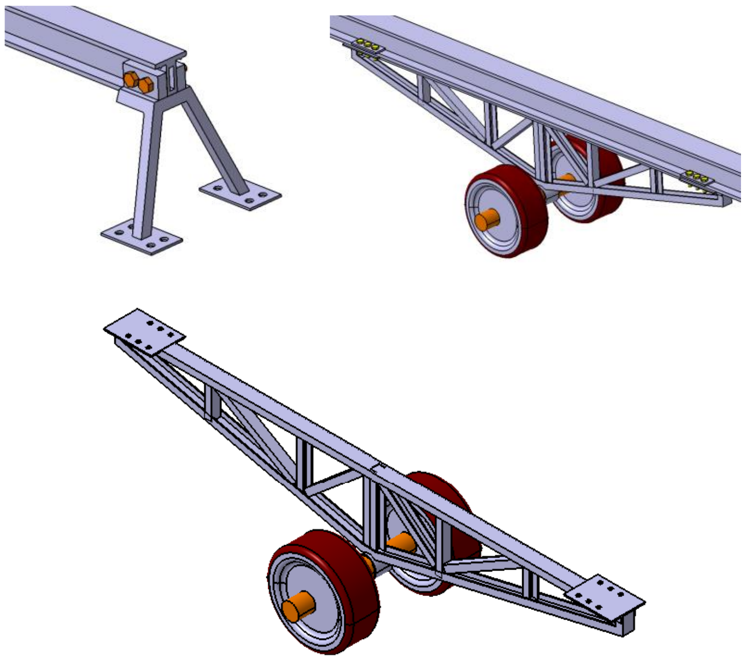


Fig.2.5 - Launcher Support

2.3.2 Cradle

The role of the cradle in the launch process of the UAV is very important. The cradle is responsible for transmitting the power of the launching device to the UAV and is the core functional component of the UAV launching device. The main functions of the cradle are: (1) It is responsible for transmitting power to the drone. (2) Responsible for supporting the drone and maintaining the attitude of the drone during the launch process. According to the function of the cradle, the detailed design requirements for the cradle are as follows:

1. The four cantilevers of the cradle are responsible for loading the motor and the propeller, so the size of the cantilever cannot interfere with the size of the propeller, and the strength needs to meet the thrust requirements.

2. The front and rear support arms should be able to coordinate with the size of the UAV, and should not only be able to provide support for the UAV, but not affect the take-off of the UAV.

3. The size of the cradle should be coordinated with the launcher, and it can successfully complete the sliding action on the launcher.

The drone runs on the track to achieve a predetermined speed through the cradle to achieve take-off. The cradle relies on 6 wheels to achieve stable positioning on the launch track and running on the track. The four corners of the cradle have a cantilever, A motor and propeller are mounted on each cantilever.

The cradle generally includes: the main structure of the cradle, four cantilevers, front support arms, rear support arms, and hooks on both sides for brake. The main part of the cradle is responsible for connecting the launcher, the four cantilevers are equipped with motor propellers, and the forearm and rear arms are used to support the drone. The structure of the cradle should be as simple as possible based on satisfying the smooth take-off of the UAV, and meet the design requirements with the smallest weight. The picture (Fig.2.6) shows the digital model of the drone launch cradle.

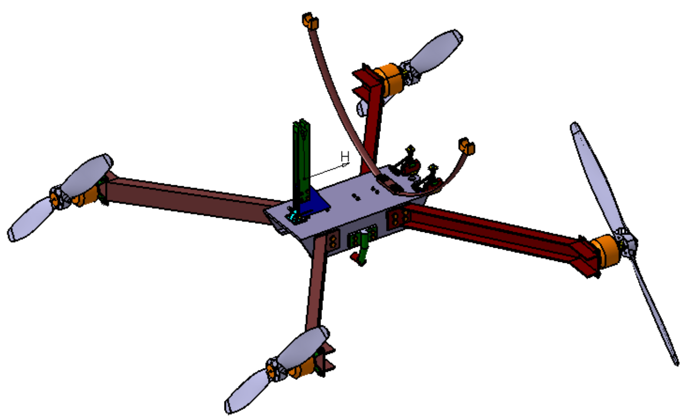


Fig.2.6 - Launch Cradle

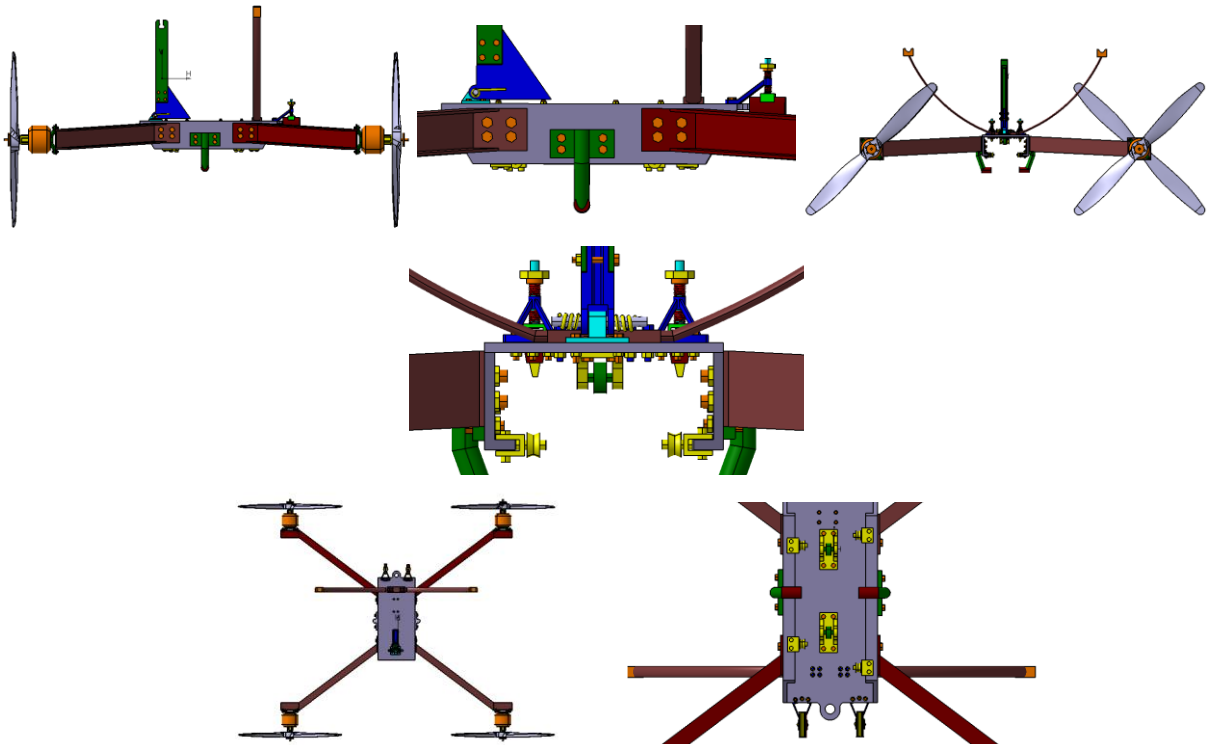


Fig.2.7 - Views of the cradle

The cradle is assembled from various parts and connected with bolts, which facilitates the maintenance of the cradle and the replacement of damaged parts.

In the design of the cradle structure and size: the size of the cantilever should be coordinated with the size of the propeller selected later and the size of the UAV, and there should be no interference in position; The position and distance of the front and rear support arms need to be determined according to the center of gravity and size of the drone. it needs to be able to support the drone stably; the wheels on the cradle must match the runway of the launcher.

The following Fig. 2.8 a b is the front support arm on the cradle, c d is the rear support arm on the cradle, the front and rear support arms are used to provide support for the launching drone. The front support arm is also responsible for the power transmission of the UAV during the launch process. There is a shaft at the bottom of the forearm, the forearm can rotate around it, and the torsion springs on both sides of the shaft can keep the forearm in a forward tilting trend. Its function is to avoid the take-off path of the drone when the drone takes off at the end of the launch track to prevent collision with the drone, thereby preventing damage to the fuselage.

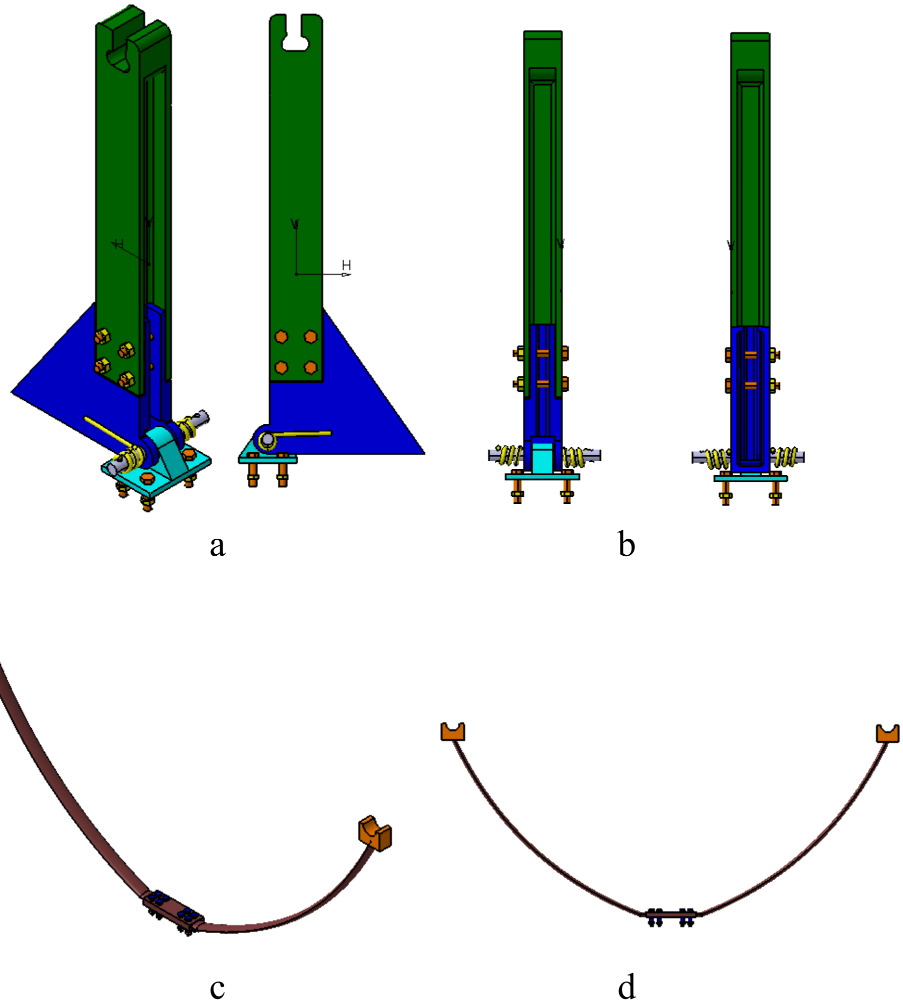


Fig.2.8 - Front and rear support arms

The launch thrust is to make the drone take off normally. Therefore, the power and thrust of the selected motor need to meet the design requirements, and then the model of the propeller is selected according to the model of the motor. The standard for motor selection are as follows：

Table 2.2 - Motor parameters

Voltage (V)	Propeller (RPM)	Throttle (%)	Current (A)	el.Power (W)	Efficiency (%)	Thrust (g)	Spec. Thrust (g/W)
51.8V (14S LIPO)				28x10(2-blade)			
	3600	54	32.2	1643	91	9201	5.6
	4000	61	44.4	2242	91.3	11435	5.1

4400	68	59.6	2988	91.5	13745	4.6
5200	83	100.8	4929	91.5	19224	3.9
5600	91	128.1	6164	91.3	22192	3.6
5998	100	161.7	7619	90.9	25904	3.4

The motor selects DUALSKY GA8000.9&9S140KV, the voltage selects 14S, and the ESC selects 200A and up HV ESC. Choose carbon fiber propellers, which can produce 25.9kg of pulling force at 100% throttle. Selecting 4 motors can generate a pulling force of 103.6kg. The propellers are arranged on both sides of the cradle, and each cantilever is equipped with a propeller and a motor.

The power supply system of the cradle: adopts the current collector system. Including compact current collector and guide rails, the brushes are the main device for the collector side to pick up electric energy in the sliding contact line system in the launch system. It is directly conducted to the motor propeller on the cradle, to realize the mobile power supply of the system. The sliding contact wire collector is composed of the tension device of the mechanical structure as shown in the right side in Fig. 2.9, and the collector brush that slides in contact with the guide rail. A collector is installed at the rear of the launch cradle, and a sliding contact line is installed on the launch track. The motor propeller device on the cradle realizes the power-on operation through the whole composed of the collector and the sliding contact line device.

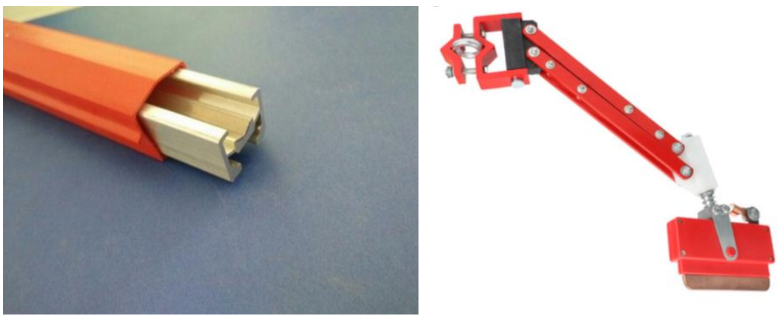


Fig.2.9 - Current collector

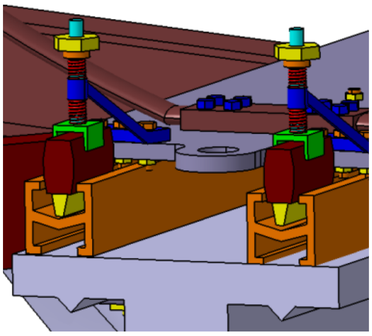


Fig.2.10 - Current collector system

Since the maximum current of the motor can reach 161.5A during operation, the maximum current of the four motors is 646A. The multi-stage current collector can carry a small current, while the unipolar current collector can cradlery a large current, so the unipolar current collector is selected on the transmitting cradle. A choice of two unipolar current collectors with a standard of 350A suffices.

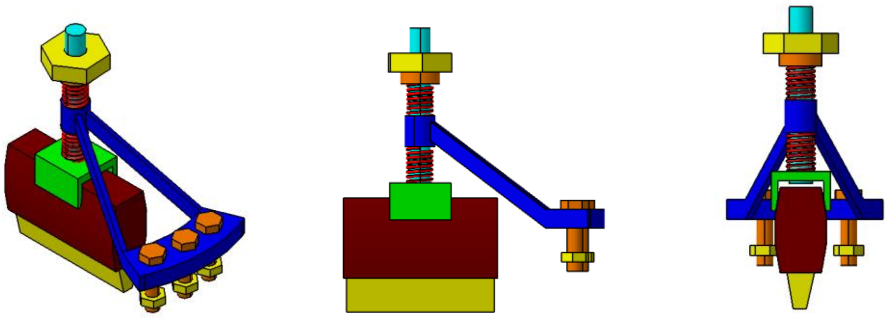


Fig.2.11 - Current collector digital model structure

2.3.3 The Buffer System

The buffer system of the launcher needs to absorb the energy of the impact of the cradle, and cannot make the trolley rebound to prevent secondary damage. Therefore, the buffer system designed in this section can not only absorb the impact energy when the cradle reaches the end of the launch track, but also can block the position of the cradle to prevent rebound. Limit to prevent its rebound from causing damage to itself and the cradle structure.

The buffer system is located at the end of the launch track and is mainly consist of two parts, the hydraulic buffer at the end of the launch track and the polyurethane rod at the end of the launch frame. There are two polyurethane rods at the end of the track, the inner part of the two polyurethane rods is C-shaped section steel, and the two polyurethane rods are at a small angle, which can make the cradle friction and decelerate at the end of the launch track, so that the speed of the cradle decreases rapidly.

After the drone takes off, the cradle collides with the buffer at the end of the launch track, and the cradle stops quickly. The selected buffer needs to be able to absorb the energy when the cradle hits. The load energy calculation formula needs to be based on the correct impact model. The impact model is generally divided into horizontal impact, free fall, rocker impact, and rotational impact. Estimated as horizontal impact when calculating load energy. And it is assumed that the full kinetic energy of the cradle device is converted into the energy when hitting the hydraulic shock absorber.

$$E = \frac{1}{2}mv^2$$

From the above formula, it can be concluded that the kinetic energy of the cradle is 3125J.

Then select the specifications of the buffer according to the kinetic energy and table 2.2 below: Adjustable automatic compensation hydraulic buffer as shown below:

Table 2.3 - Spring buffer parameters

Specification	Stroke mm	maximum absorbed energy （Nm）	Energy absorbed per hour (Nm/h)	maximum effective weight (kg)	maximum impact speed (m/s)	weight (g)
ACJ1210	10	10	30000	80	4	43
ACJ1412	12	20	36000	160	4	75
ACJ2020	20	60	50000	960	4	189
ACJ2525	25	100	75000	1600	4	308
ACJ2550	50	150	85000	2400	4	395
ACJ2725	25	140	85000	2240	4	396
ACJ2750	50	250	95000	4000	4	510

ACJ3325	25	180	100000	2880	4	540
ACJ3350	50	300	110000	4800	4	800
ACJ3625	25	220	125000	2500	4	750
ACJ3650	50	350	130000	5600	4	950
ACJ4225	25	250	150000	5600	4	1150
ACJ4250	50	700	180000	11200	4	1420
ACJ4275	75	1050	210000	16800	4	1720

Fig.2.12 -Spring buffer

According to the above table and calculated data, 3 ACJ4275 can be selected.

The rear limit is made of urethane rubber rods. Two C-shaped section steels face the two urethane rubber rods to the opening of the cradle, which is slightly larger. The opening is larger than the diameter of a cylindrical structure on the cradle, and the two urethane rods are at a small angle. As shown in Fig.2.15:

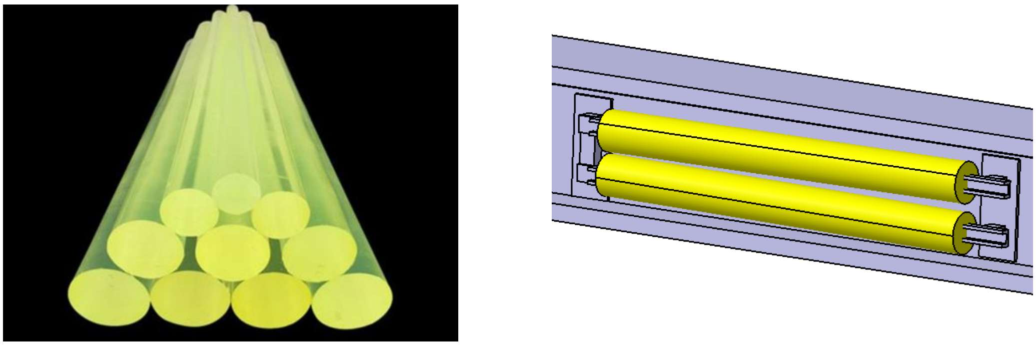


Fig.2.13 - Polyurethane rubber rod and its limit device

A cylindrical hook structure on the cradle is used for the limit action of the cradle at the end of the launch track. The cylindrical structure is covered with rubber-plastic cotton, and the rubber-plastic cotton is deformed. When the cradle reaches the end of the guide rail, the position will gradually get stuck, and finally the cradle stops at the end of the launch track without rebound.

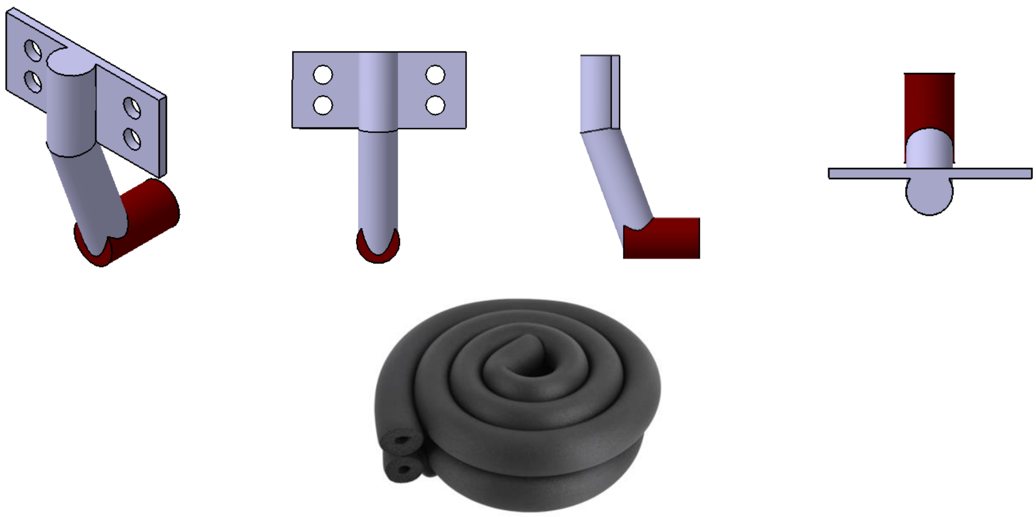


Fig.2.14 - Limit hook and rubber cotton

As shown in the assembly diagram below: the hydraulic buffer at the end of the launch track consists of 4 parts: the overall support frame is welded from steel plates, 3 ACJ4275 adjustable automatic compensation hydraulic punches, and Spring steel for locking the forearm of the cradle, rubber pads.

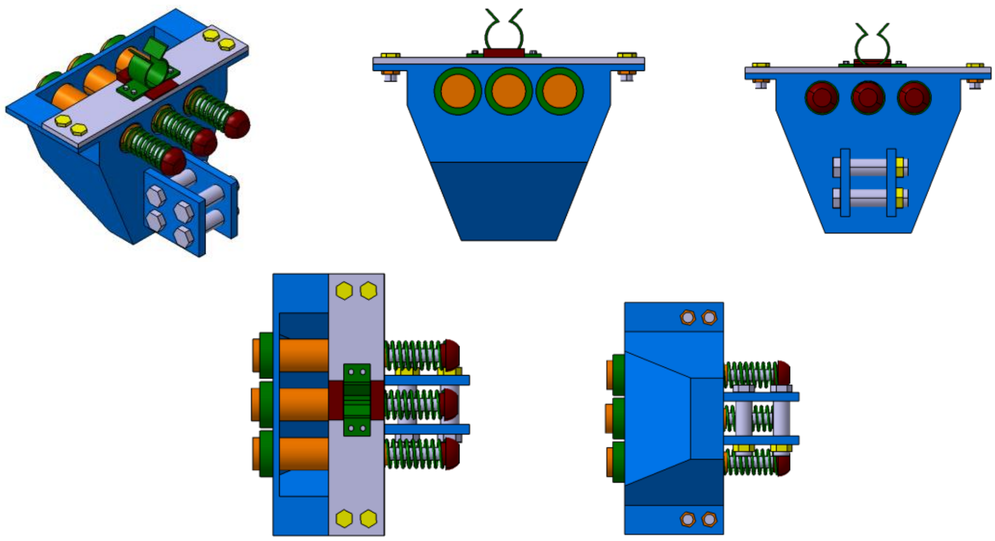


Fig.2.15 - Buffer system

When the cradle is approaching the end of the polyurethane rod, the front end of the cradle begins to contact the hydraulic punch at the end of the launch track, and the buffer can quickly absorb the energy of the cradle's impact, thereby making the cradle stop quickly. The advantage of the combination of the two parts of the shock absorber is that the cradle can not only stop smoothly at the end of the launch track, but also prevent rebound under the friction of the rubber shock absorber, to avoid collision and damage to the cradle. The buffer system is equipped with spring steel, which is used to lock the forearm of the cradle after the cradle reaches the end of the track to release the drone to prevent the forearm from rebounding and causing damage.

2.3.4 Locking Device

Locking device, the locking device is used to lock the drone and the cradle before taking off. When preparing to launch, after starting the motor propeller, the propeller of the cradle needs to run smoothly before launching. Therefore, the locking device is responsible for releasing the drone and the cradle with a predetermined thrust after the system runs smoothly, and the whole body of the drone and the cradle is ejected quickly.

The locking device is mainly divided into two parts: the first part is the locking structure part of the locking mechanism; the second part is the control part of the locking mechanism. The structure of the locking structure of the locking device is designed based on the principle of the Janney Coupler. The purpose of locking is achieved by two couplers engaging with each other. The coupler A is connected to the cradle, and the coupler B is connected to the launcher. The cradle passes through the rear hook before launching. A and B are connected to lock, and the hook A connected to the cradle maintains a certain shape. By gradually contacting the hook B, the hook B connected to the launch track rotates gradually. After the rotation reaches the specified angle, the electromagnetic locking mechanism on the hook B will lock the hook B, and the locking instruction is issued by the electromagnet on the locking mechanism. device executes.

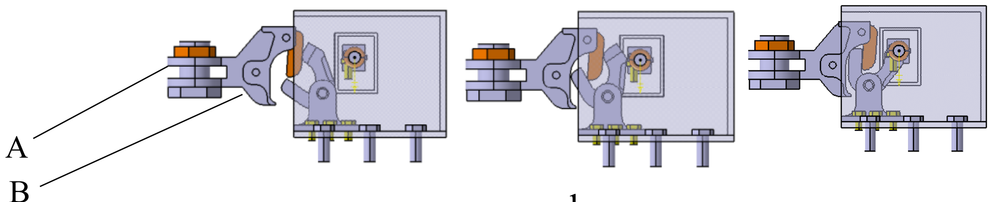


Fig.2.16 - Hook contact state at different times

The Fig.2.18 shows the three states of the locking device from contacting to locking. In the Fig.2.18, a is when the hook A on the cradle has just started to contact, b is in the process of contact between the hook A and the hook B. The hook A and the hook B are locked. At this time, because the electromagnet is activated, the hook B will be stuck in the locked state, and the spring is in a compressed state.

After receiving the command, the electromagnetic locking mechanism on the hook B will keep the spring on the shaft in a compressed state. At this time, the hook is locked and cannot be rotated. When the electromagnet is released, the spring will move the stopper on the hook. When the hook can rotate freely, the cradle is unlocked.

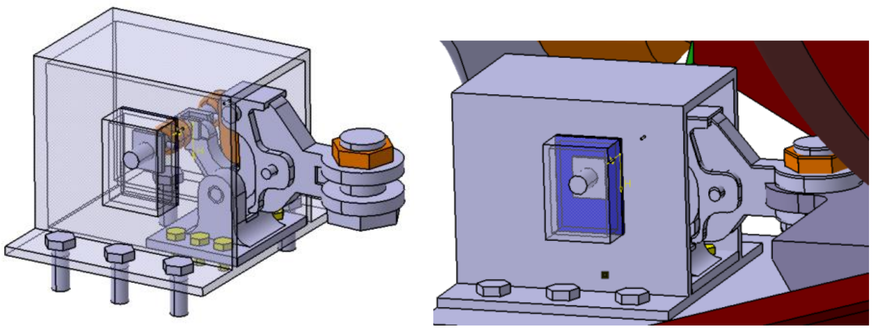
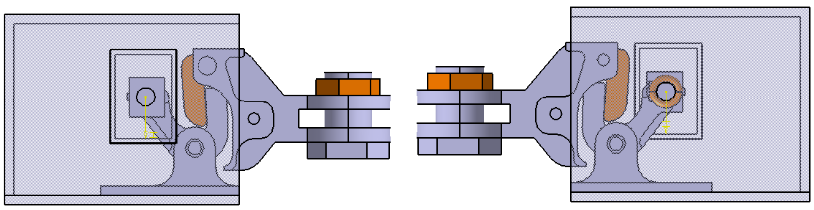


Fig.2.17 - Locking device



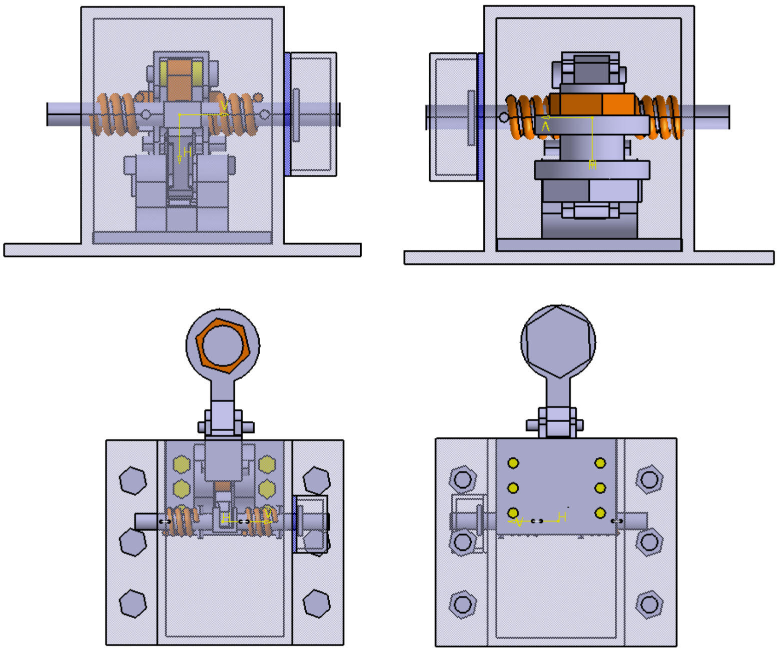


Fig.2.18 - Structure view of locking device

2.3.5 Digital assembly of UAV launch system

The UAV launch system is a system engineering. The use of digital assembly can reduce the cost of manpower, material resources and time, and can improve the success rate and accuracy of the later installation and commissioning of physical objects Coordinate the size and position of all parts of the drone launcher, and adjust the unreasonable places.

The UAV launch device involves many parts, and it is necessary to consider the two states of the assembled components during installation and operation. The digital assembly can check the size and structure of the installed parts when they are stationary. The position and angle of some parts can be adjusted to simulate the working state, it is more comprehensive to check whether there is interference in the position and size of each component, and to modify the problematic structure and size.

Table 2.4 - Launcher Parts

Number	name
1	launch track

2	launch frame A
3	launch frame B
4	cradle
5	motor
6	propeller
7	Rubber reducer
8	hydraulic shock absorber
9	current collector system
10	locking device

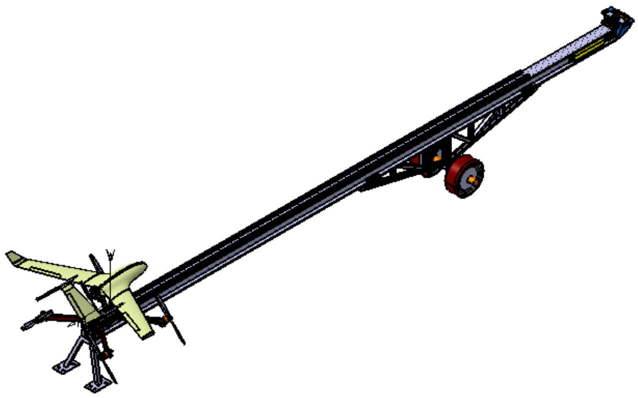
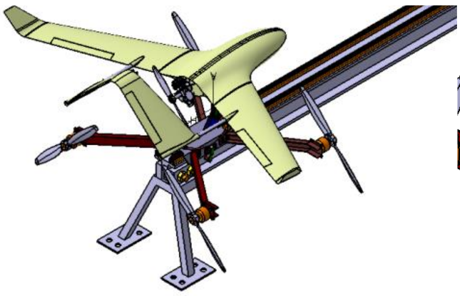
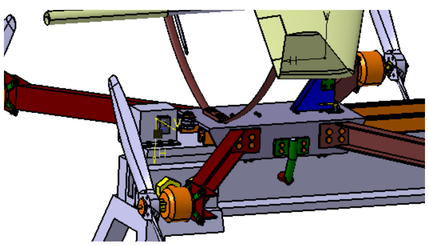


Fig.2.19 - Launcher assembly





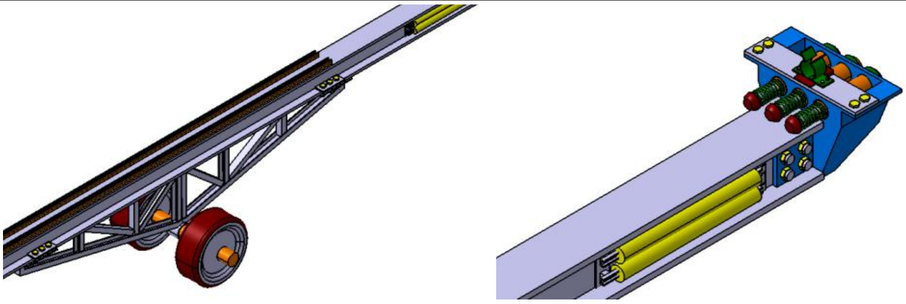


Fig.2.20 - Launcher assembly

PART 3. LAUNCH SYSTEM STATIC CHECK

The components of the UAV launch system need to meet the strength and stiffness requirements. Static analysis can check the dangerous components and structures of the UAV launch system to ensure its safety and reliability. Through the finite element simulation calculation of the structure, the stress distribution and deformation of the parts can be obtained, which can not only judge the strength and stiffness of the parts, but also can be used as the basis for the weight reduction and optimization of the parts.

3.1 Finite Element Method

The finite element method is to use the integral method to establish a system of algebraic equations, and use a continuous function to approximately describe the solution of each element. Since the internal elements are continuous, the solution to the entire problem can be obtained by assembling a single solution [20]. Based on the static analysis module in ANSYS/workbench, this section meshes the parts of the launcher, sets constraints, applies external forces, and finally submits it to the solver for calculation, to obtain the force Stress Strain Results.

The common methods of finite element derivation of finite element formula include: direct method, imaginary displacement method, minimum potential energy method, variation method, weighted residual method. There are three main steps in finite element analysis: preprocessing stage, solution stage, and postprocessing stage.

Table 3.4 - Finite element method solution analysis

Phase	Step
Preprocessing Phase	1. Establish a solution domain and discretize it into a finite number of elements. 2. Assume that the element shape representing the physical behavior of the element is the element shape function 3. Establish an equation for the element. 4. Group the elements into an

	overall problem and construct an overall matrix (such as the overall stiffness matrix, displacement vector matrix, and force vector matrix in structural analysis). 5. Apply boundary conditions, initial value conditions and loads according to the balance equation.
Solving Phase	Solve a system of linear or nonlinear differential equations, and get the solutions of the nodes, such as the displacement or temperature values of different nodes.
Post-processing Phase	Obtain other derived quantities such as stress, strain in the structural field, heat flux in the temperature field. Verify the results and understand the problem.

3.2 Case Simulation

Calculate the maximum deflection and stress at the free end of a cantilever beam. The material of the cantilever beam is steel 45, and a concentrated force F of 1KN is applied to the free end of the cantilever beam. The diameter D of the circular section of the beam is 100 mm, and the length L of the beam is 1 m. The elastic modulus E of steel is 2E11N/m2, and the Poisson's ratio u is 0.3.

According to the mechanics of materials, the moment of inertia of the circular section beam can be obtained as:

$$I = \frac{\pi D^4}{64} = 4.9 \times 10^6$$

According to the theory of material mechanics, the cantilever beam stress is calculated as:

$$\sigma = \frac{M}{W_Z} = \frac{32M}{\pi D^3} = 10.2$$

The maximum deflection of the free end of the cantilever beam is:

$$W = \frac{FL^3}{3EI} = 3.4 \times 10^{-4}$$

According to the above example, import the established calculation model into the Statics static analysis module in ANSYS/workbench, place a fixed constraint on one end of the cylinder, and apply a 1000N load to the other end, and then perform static simulation. The results are shown in the following Fig 3.23:

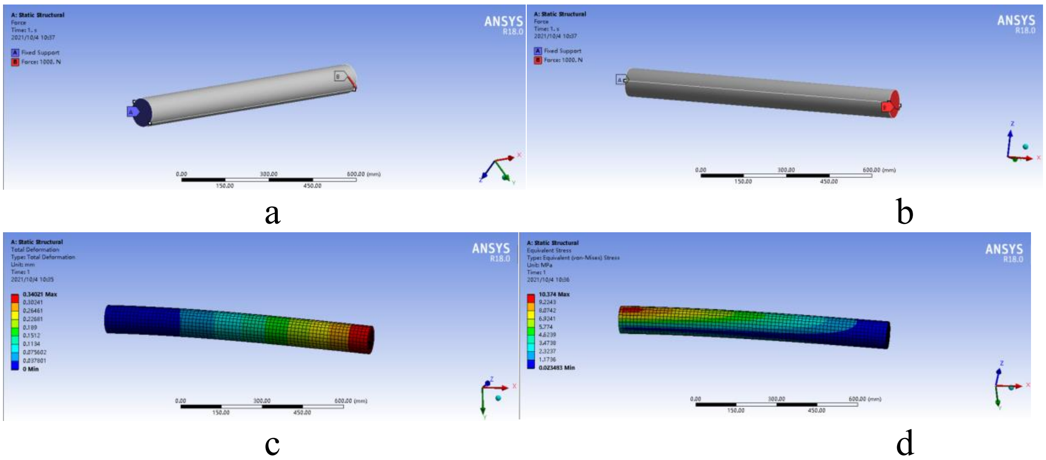


Fig.3.1 - Cantilever beam statics simulation results

Fig a and Fig b are the constraints and forces on the cylinder in the example. Fig c and Fig d in the above figure are the deformation and stress cloud diagrams of the example cylinder after being subjected to force, respectively. From the Fig c, it can be obtained that the maximum deformation of the example cylinder occurs at the free end, the deflection is 0.34021mm, and the theoretical calculation value is 0.34mm. The maximum stress of the example cylinder occurs at the fixed end, the value is 10.374Mpa, and the theoretical calculation value is 10.2 MPa. The difference between the maximum stress and deflection and the theoretical calculation values is very small, so the calculation results of the static analysis module in the finite element software are reliable and worthy of reference.

3. 3 Parts Check

Description of the launch process of the drone: place the cradle at the rear of the launcher and lock the cradle. Currently, place the drone on the cradle, lock the drone with the forearm of the cradle, and drag the rear arm of the drone with the tail brace of the drone. Start the motor to drive the propeller. After the system is stable, prepare to launch and unlock the cradle. Now of unlocking, the cradle and the drone move quickly along the launch track. When it moves to the end of the launch track, the plane takes off, and the cradle is braked suddenly due to the damping device at the end of the launch track.

According to the launch process of the UAV and the analysis of the structure, the parts with larger and more concentrated forces can be obtained:

Table 3.5 - Structural stress need to be checked for the launcher part

Structure	Force
Round hole at the rear of the cradle	1015.26N
Cantilever	253.82N
front support arm	1015.26N
locking device top iron	1015.26N
locking device hook	1015.26N
Locking device hook attached to the cradle	1015.26N

Next, perform a static check on dangerous structures and parts:

The round hole at the rear of the cradle must bear most of the pulling force of the power unit, so it is analyzed as follows:

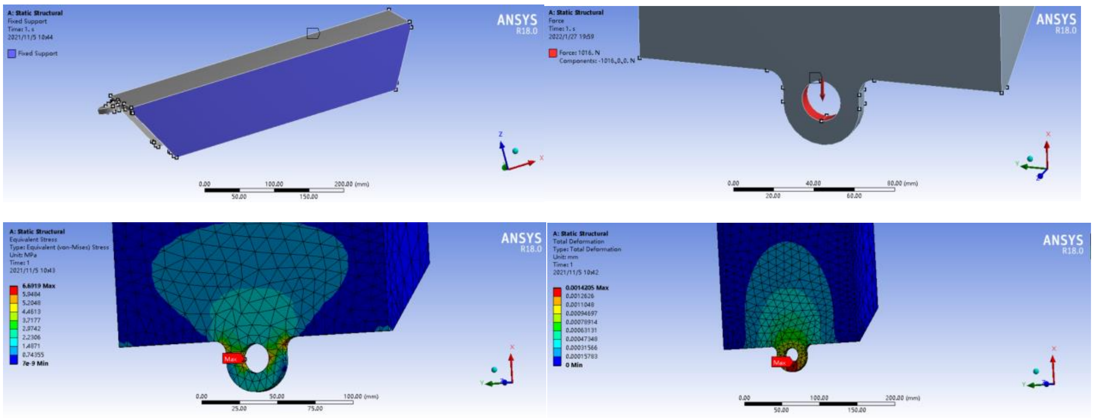


Figure 3.2 - Static analysis results of the round hole at the rear of the cradle

The cantilever is responsible for transmitting the thrust of the propeller motor to the cradle, So the cantilever analysis is as follows:

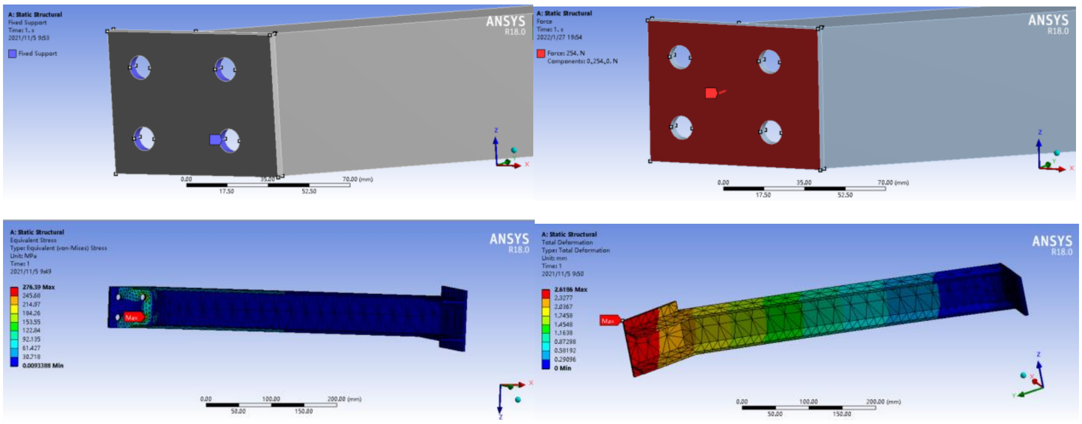


Figure 3.3 - Static analysis results of the trolley cantilever

The front support arm is responsible for transmitting the power of the car to the drone body, so the analysis of the front support arm is as follows:

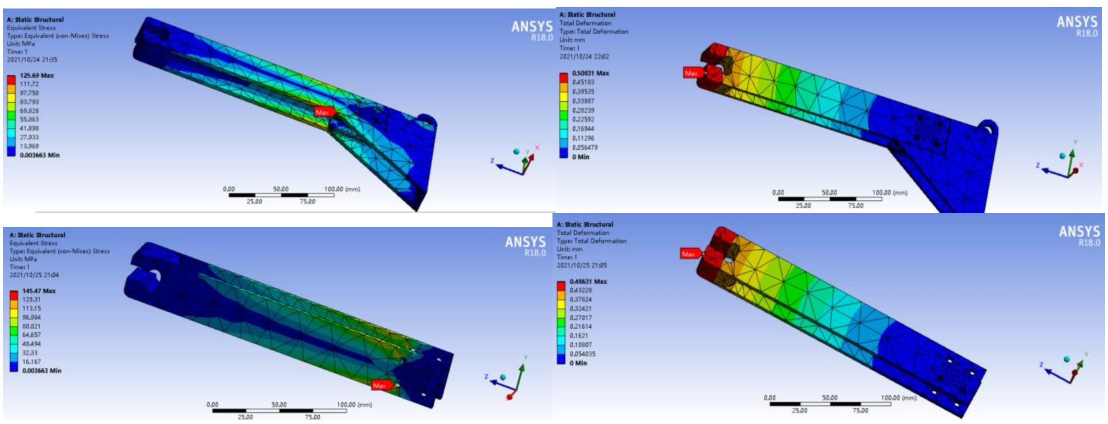


Figure 3.4 - Static analysis results of the front support arm

Regarding the force of the hook: the hook is subjected to tension, and the force of the top iron when it is stuck on the hook is an upward force， so：

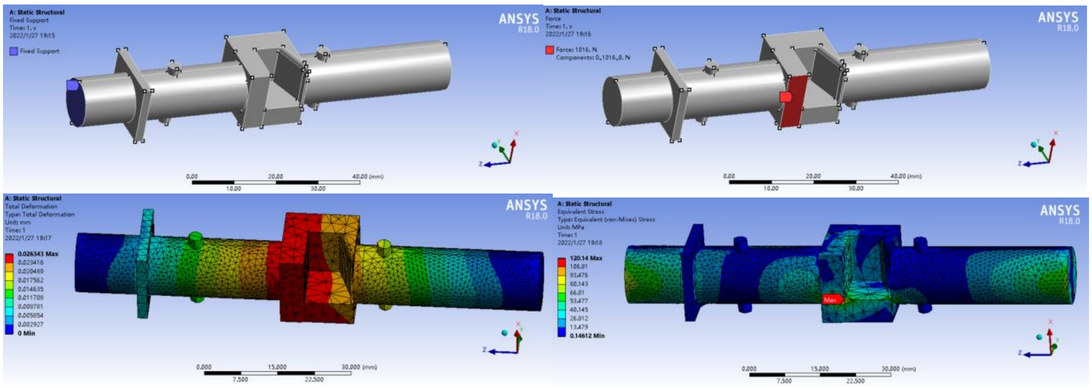


Figure 3.5 - Static analysis results of the top iron of the locking device

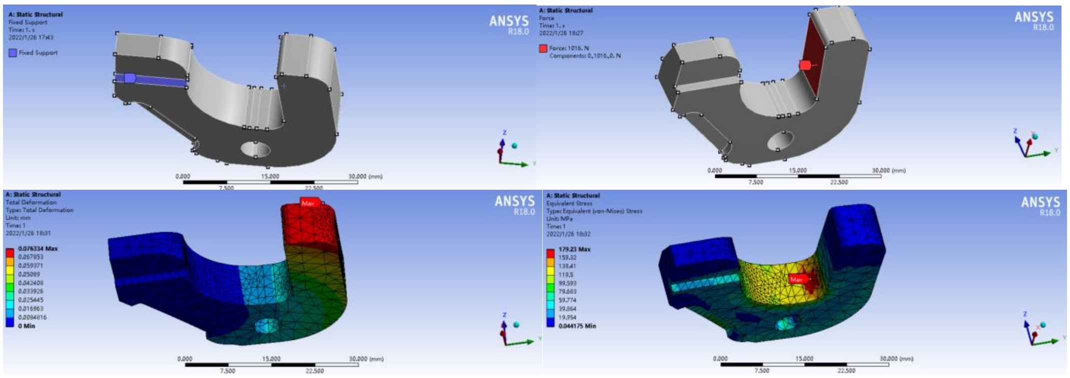


Figure 3.6 - Static analysis results of the locking device hook

Locking device hook on cradle：

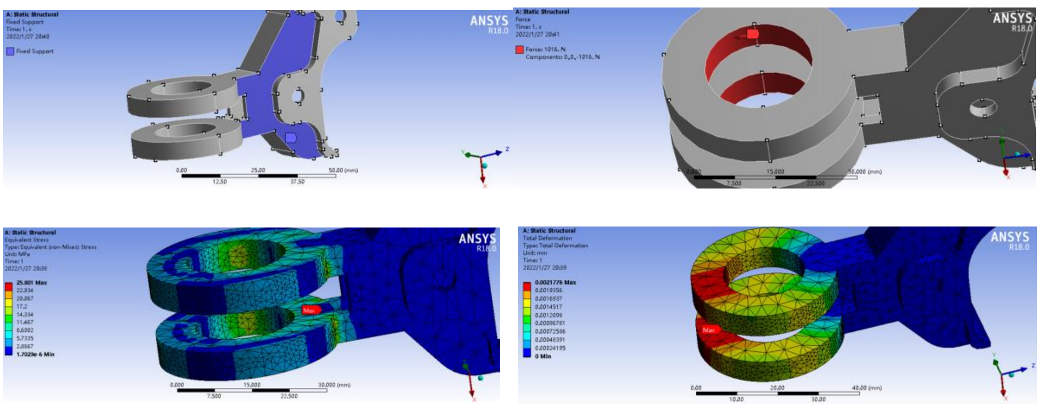


Figure 3.7 - Static analysis results of the hook of the trolley end locking device

When using the finite element static analysis of the structure, the mesh has a certain influence on the calculation accuracy of the results. In the calculation and the solution results, the results of the finite element analysis of parts and structures conform to the stress distribution law, which is consistent with the Engineering experience; and the maximum stress value tends to be stable as the mesh accuracy increases in the calculation. To sum up, it can be shown that the static analysis results of the parts are worthy of reference.

Perform static inspection and verification on possible dangerous parts, modify and strengthen the structure for the dangerous parts in the initial verification, and then re-check. In the end, all dangerous parts passed the check safely. Finally, the structures mentioned in Table 3.4 are subjected to static checking respectively, and the maximum stress and maximum deformation of the structure are obtained respectively. The data are shown in the following table:

Table 3.6 - Static analysis results of part of the launcher structure

Structure	Material	Yield Stress MPa	Max Stress MPa	Max Deformation mm
Round hole at the rear of the cradle	7075 Aluminum alloy	503	6.6919	0.0014
Cantilever	7075 Aluminum alloy	503	276.39	2.6186
front support arm	7075 Aluminum alloy	503	145.47	0.4863
locking device top iron	Q235	235	120.14	0.2634
locking device hook	Q235	235	179.23	0.0763
locking device on cradle	Q235	235	25.801	0.0022

According to the statics simulation data obtained in the table, it shows that the verified dangerous structures all meet the requirements. In the process of calculation and verification, the dangerous structures and parts were modified, and finally the strength and stiffness requirements of the structure were met.

Conclusion to part 3.

In this part, the UAV launch device is designed first, including the design of the launch track, cradle, and deceleration device at the end of the track, as well as parameter selection of the power device and power supply device. Digital assembly to modify the unreasonable parts of the launch system. Finally, according to the force characteristics of the launch system, the finite element static analysis is carried out on the dangerous structures and parts, and the positions where stress concentration and strain are likely to be generated during the launch of the UAV are analyzed and calculated. The parts and components have been improved, and finally ensured that each part and structure of the design can meet the requirements.

PART 4. MODELING AND SIMULATION OF UAV LAUNCH DYNAMICS

The UAV launch dynamics simulation is an analysis and inspection of the entire launch process. Through the establishment and simulation of the dynamic model of the launch process, parameters such as the speed of the launch end, the acceleration during the launch process, and the displacement of the entire launch process can be obtained. It is an indispensable part of the whole design process.

4.1 Establishment of the dynamics model of the UAV launch

Based on the established digital model of the launcher and the obtained aerodynamic parameters of the UAV, the dynamics of the UAV launching process is modeled, and the established model is simulated.

For the drone on the launch frame from stationary to take-off. In this process, the drone and the cradle accelerate during the take-off process, and the whole body of the cradle and the drone is subjected to the following forces: the thrust generated by the propeller, the friction between the cradle and the track, and the air drag force of the drone, the component of the total weight of the cradle and the drone, and the component of the lift force of the drone：

Symbol Description:

Table 4-1 Symbol Explanation

Symbol	Meaning
F_l	propeller thrust
ρ	Air density
F_f	friction
u	friction coefficient
F_N	pressure perpendicular to the track
m_T	Total weight of cradle and drone
D	Drag Force
L	Lift Force
θ	launcher angle
S	wing area
C_L	Lift coefficient
C_d	Drag coefficient

The thrust generated by the propeller is driven by the motor to generate a continuous and stable thrust. Thrust data is available for the motor propeller selected in part 2:

$$F_l = 1015.26N \tag{1}$$

The frictional force is created by the friction between the cradle and the track:

$$F_f = uF_N \tag{2}$$

In the calculation, it is assumed that the thrust direction of the engine is at the same level as the plane of the track, so the positive pressure consists of two parts:

The positive pressure consists of the following two parts:

$$F_N = \quad Gcos\theta - \quad L \qquad (3)$$

$$L = \frac{1}{2}\rho v^2 SC_L \qquad (4)$$

And：

S is the projection of the wing on the XOZ surface, where the value is 1.42

C_L is the lift coefficient

Drones create drag force during launch:

$$D = \frac{1}{2}\rho v^2 SC_d \qquad (5)$$

According to Newton's second law, for the whole body of the cradle and the UAV

$$m_T a = F_l - F_f - D - \quad Gsin\theta \qquad (6)$$

3 of them vary in amount:

Integrating both sides of the equation over the length l can have:

$$\frac{1}{2}m_T v^2 = \int_0^l (F_l - F_f - D - \quad Gsin\theta)\, d_x \qquad (7)$$

and

l is the length of the track

v is the velocity at the end of the ejection

When the drone derails, the lift needs to be greater than the gravity of the drone so that the drone can take off successfully. The elevation angle currently needs to satisfy the following relationship

$$\frac{1}{2}\rho v^2 SC_L \geq mg$$

To find C_L needs to be greater than 0.38, so according to the aerodynamic parameters of the UAV, it can be obtained that when the angle of attack is greater than 5°, the UAV can take off normally. Then, according to the table of lift coefficient and drag coefficient obtained, it can be obtained that when the angle of attack is 6°, the lift-to-drag ratio is the largest, so the launch frame angle is determined as 6°

In summary, the combination of formulas (1) to (7) can obtain the UAV and the cradle as a body on the track:

$$m\frac{ds}{dt} = F_l - u(G\cos\theta - \frac{1}{2}\rho v^2 SC_L) - \frac{1}{2}\rho v^2 SC_d - \quad G\sin\theta \qquad (8)$$

4.2 Dynamic Simulation Parameters and Models

Table 4.2 - Simulation parameters

Symbol	Meaning	Value
F_l/Kg	propeller thrust	103.6
u	friction coefficient	0.08
m_T/Kg	Total weight of cradle and drone	30
θ/°	launcher angle	6
C_L	Lift coefficient	0.52
C_d	Drag coefficient	0.032
$\rho/\left(kg\cdot m^{-2}\right)$	Air density （20°）	1.205
S/m^2	wing area	1.42

According to the launcher dynamics model established in the previous part, a simulation model is established in the MATLAB/Simulink environment [21] Figure 4-1, and the data in Table 4-2 is substituted into the simulation to obtain the UAV and the acceleration, speed, and displacement curve of the cradle during the launch process.

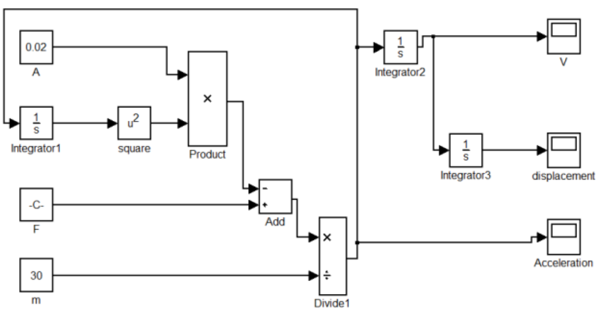
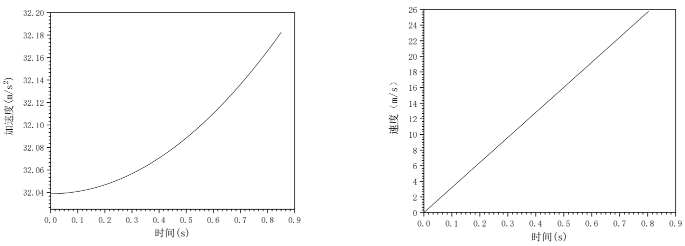


Fig. 4.1 - Simulink simulation model of UAV launch process

4.3 Simulation results analysis of UAV launch process

After the simulation data is set, the dynamics simulation of the UAV launch is carried out in the MATLAB/Simulink environment. The entire UAV launch process is very fast. When the power is turned on, the motor propellers on the cradle are all started, and the operation is stable. The moment when the unlocking device is turned on and the cradle is unlocked, about 1second, the drone completes the ejection process.

In Figure 4.2, a is the change of acceleration with time, b in Figure 4.2 is the change of speed with time, and Figure 4.3 is the change of distance with time. As it can be seen from a in Figure 4.2, the acceleration change during the entire launch process is very small, and the entire launch process is very stable, which also reflects the advantages of the motor propeller as a power device; from b in Figure 4-2, the speed reached 25m/s in 0.8 seconds, and the whole process was fast and smooth. Figure 4-3 shows the change of distance with time. At about 0.8 seconds, that is, when the speed of the cradle and the drone reaches the take-off speed of 25m/s, the displacement currently is 9.925m.



a b

Fig.4.2 - UAV launch acceleration and speed

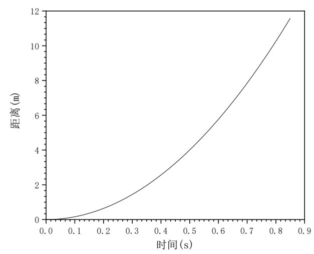


Fig. 4.3 - UAV launch displacement

The figure shows the curve of the acceleration, velocity, and displacement of the UAV and the cradle during the launch process with time.

According to the characteristics of the acceleration and speed change with time of the UAV and the cradle during the launch process, the following acceleration and speed change characteristic table can be obtained:

Table 4.3 - Acceleration and Velocity Change Characteristics Table

Phase 1 （start up）	acceleration	+
	velocity	0
Phase 2 （accelerate）	acceleration	+
	velocity	+
Phase 3 （buffer）	acceleration	-
	velocity	+

(It is assumed that the speed and acceleration are positive along the launch direction of the drone, marked with "+", and the reverse is "-".)

From the above table, it can be concluded that during the launch of the drone, the state of the cradle and the drone can be roughly divided into three stages, which are mainly based on the changes in the speed and acceleration of the cradle during the overall launch process: The first stage is the start-up stage— The motor propeller works but the cradle is locked, and the speed displacement is 0. Currently, the acceleration reaches the maximum along the direction of the launch track; The second stage is the acceleration stage—the whole body of the cradle and the UAV accelerates rapidly. During this process, the acceleration will change slightly due to the aerodynamic lift force and drag force of the UAV and the frictional force with the track; the third stage is the buffer stage when the cradle is separated from the drone, and the speed of the cradle decreases rapidly at the end of the track until it stops.

Through these three stages, the UAV launch process can be better described, which provides a clearer reference for improving the entire launch system.

4.3.1 Startup Phase

The start-up phase of launching the UAV: At the beginning, the UAV is in a static state, but as the motor propeller rotates slowly and smoothly, the power output of the power system currently reaches the maximum, which corresponds to the whole cradle and UAV reach maximum acceleration. It should be noted in the startup phase of the UAV launch system that after the UAV and the cradle are installed in the locked position, turn on the power, start the motor, and then start the power unit on the cradle, and the motor drives the propeller. At this time, it is necessary to wait for the propeller to rotate smoothly. Then, when ready to launch, open the unlocking device again, and the drone will be ejected instantly under the drive of the cradle.

The acceleration, speed and displacement values are shown in Figure 4.2 in Section 4.3. Currently, the speed of the UAV and the cradle increases rapidly. The speed changes the most at the beginning of the launch, and the displacement gradually increases from 0. The state of the launcher at this time is shown in Figure 4.5:

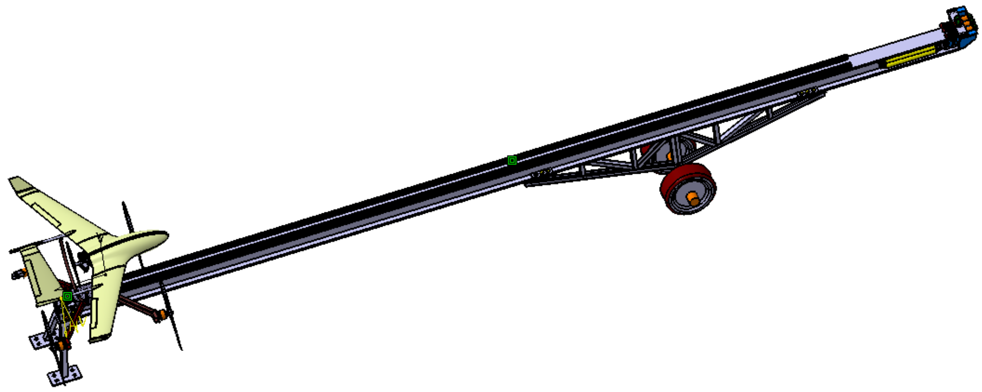


Fig.4.5 - UAV startup locked state

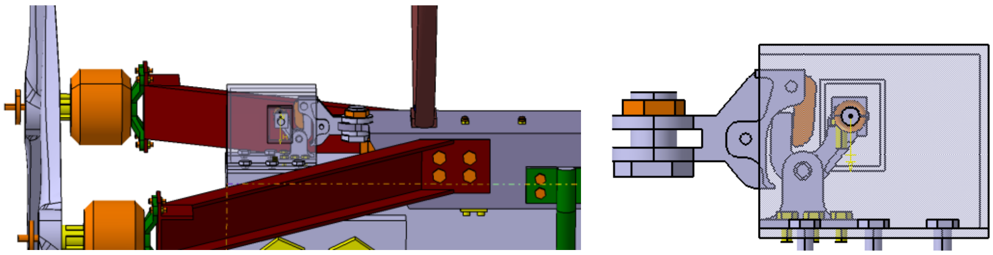


Fig.4.6 - Locking Device Status

At this time, the motor propeller on the cradle is powered on, and the engine on the drone is started. At this time, the whole body of the drone and the cradle is locked at the end of the launch track, waiting for the launch command and ready to launch.

4.3.2 Acceleration Phase

The acceleration phase means that the UAV runs on the launch track under the drive of the cradle, and the UAV is quickly accelerated to the take-off speed. The acceleration, speed and displacement characteristics of the drone and the cradle can be seen in Figure 4.2. There are two main processes in the acceleration stage during the launch of the drone. The first process is that compact current collector and guide rails on the cradle wire collector system continue to contact to supply power to the motor propeller continuously. The second process is when the whole body of the drone and the cradle reaches the designed take-off speed of the drone, the compact current collector and the guide rail are disconnected. The rails of the contact collector system stop laying near the end of the launch track.

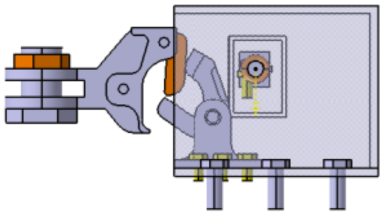


Fig.4.7 - The unlocking state of the locking device

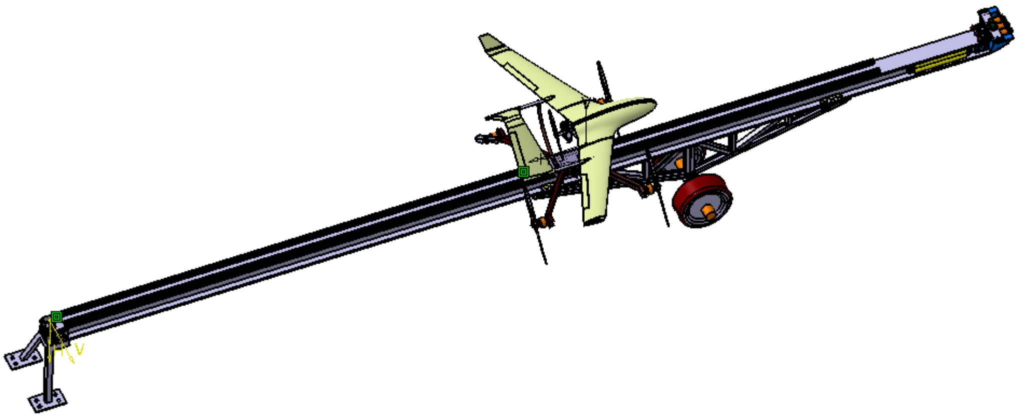


Fig 4.8 - UAV launch status in Phase 1

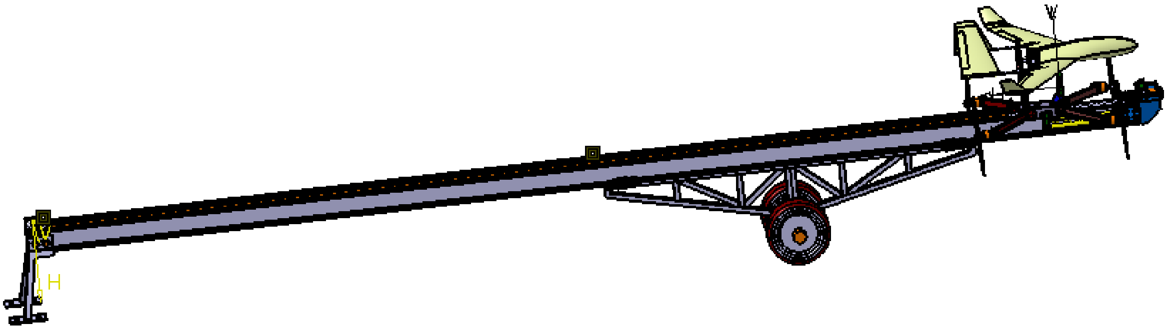
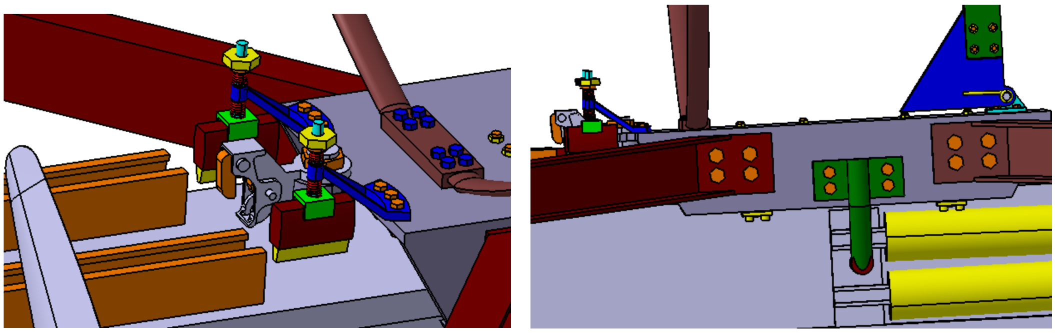


Fig. 4.9 - UAV launch status in Phase 2



a b

Fig.4.10 - Partial view of the UAV acceleration launcher in Phase 2

It can be seen from a in Figure 4.10 that the compact current collector and the guide rail in current collector system of the drone launcher have been separated, indicating that the power unit on the cradle has been cut off at this time. It can be seen from b in Figure 4.10 that the limit hook on the cradle gradually contacts the rubber buffer device at the end of the launch track. Currently, the acceleration phase is over, and the cradle starts the buffer braking phase.

4.3.3 Cradle buffer phase

When the whole body of the drone and the cradle is approaching the end of the launch track, the hook on the side of the cradle will contact the rubber limit device at the bottom, and at the same time the forearm on the cradle will tilt forward. Then the drone will fly out instantly. After the cradle enters the rubber buffer area, the position of the cradle is gradually restricted and cannot move. As shown in Figure 4.11, the forearm on the cradle will also be stuck on the spring steel of the buffer device, the front of the cradle touches the hydraulic buffer spring, the hydraulic buffer spring absorbs most of the energy left by the impact of the cradle. At this time, the drone has successfully taken off, and the position of the car is also stuck. So far, the drone has completed the ejection process

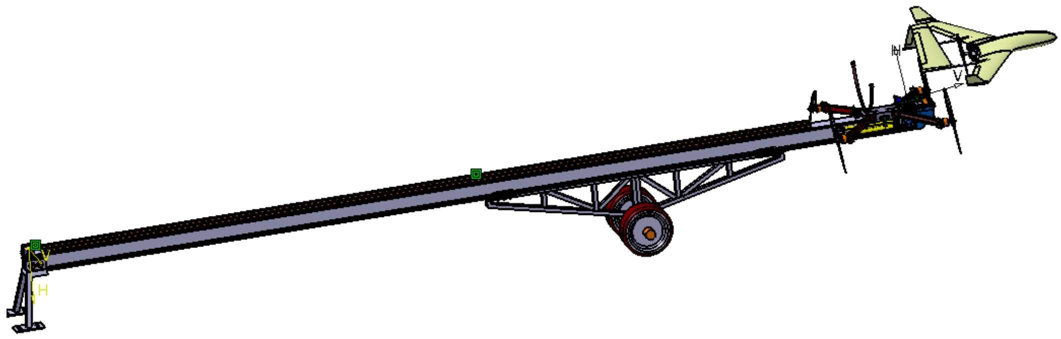


Fig.4.11 - Cradle buffer stage

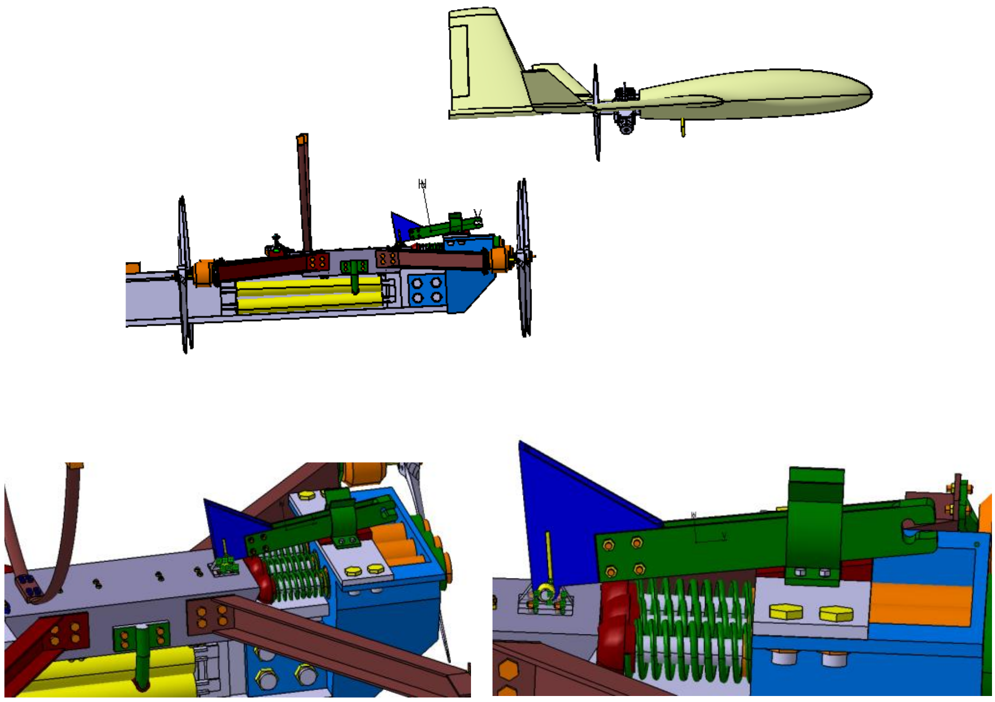


Fig.4.12 - Cradle buffer locked state

As can be seen from Figure 4.12, a partial enlarged view of the cradle buffer stage, the cradle has three parts in contact with the buffer device: first, the hook on the side of the cradle contacts the rubber at the end of the launcher, and the hook together with the cradle is finally limited. At the same time, the front end of the cradle hits the hydraulic buffer, and the hydraulic buffer begins to absorb the energy of the impact until the cradle is fully braked. The third part is the forearm of the cradle. When the drone is released, the forearm will fall forward under the action of the drone and the bottom torsion spring, and then the forearm will be stuck on the spring steel on the upper part of the buffer device, in order to prevent the forearm rotates and rebounds, causing damage to its own structure and other parts of the launcher.

Conclusion to part 4.

This chapter firstly establishes the dynamics model of the UAV launcher, and then simulates dynamic parameters in the MATLAB/Simulink environment, and finally obtains the curves of the acceleration, velocity and displacement changing with time during the launch of the UAV, and then combined with these parameter characteristics, the launch process is analyzed in stages, and the dynamic simulation results are combined with the positional relationship of the UAV, cradle and other structures in each stage of the launch process to make the launch process clearer and more intuitive. To ensure the successful launch of the launch system to provide data support.

PART 5. LABOR PROTECTION

Introduction

Workplace protection is something that every graduate student of the Master's degree should get to know, not only as a sign of responsibility for the safety of the school laboratory, but also as a sign of responsibility for the safety of one's life. In this regard, we first need to analyze our laboratory environment, the size of the laboratory, the equipment it contains, and the main work content of the laboratory. We need to analyze the hazards in the laboratory and the characteristics of these hazards to ensure that we can use the laboratory in a way that ensures personal safety, and we also need to analyze the possible hazards of fire in the laboratory to ensure that we can properly regulate the fire extinguishing process in the event of an accident. The school regulations make clear provisions for the working environment, the kind of environment in which students can complete their experiments, what harmful gases and liquids are included in the laboratory environment, and the handling of dangerous chemicals, and for the engineering environment, the specifications for the use of computers and machine tools are also very noteworthy. The following is an analysis of the university's requirements for laboratories and the hazardous elements of the working research environment, as well as how to deal with them in case of emergencies, in the context of the relevant regulations for laboratories in China and Ukraine.

5.1 Analysis of working conditions at workplace

The completion of this thesis is mainly done through computer simulation technology, also known as numerical simulation technology, which is mainly used to model the required model in 3D structure through computer software, and then import the model into the simulation software for simulation and analysis to produce results. So the experimental conditions required for the completion of this paper are a computer and a computer room, for a general computer laboratory. The computer room I used was approximately 40m^2, with a personal area of approximately 2 m^2.

The equipment used was a laptop computer, a mechanical keyboard, a computer mouse, a laptop power cord, and a power supply provided by the laboratory.

5.2 Characteristics of dangerous and harmful factors

Expert research has found that, in fact, all the daily household equipment with electricity will produce electromagnetic radiation, whether there is harm to the human body, the most important thing is to look at the size of the radiation energy.

Some specialized research institutions have tested the strength of the computer's electromagnetic field, the results found that, close to the fluorescent screen at the electromagnetic field strength of 0.9, but about 5 cm away from the screen, the strength of less than 0.1, and then a little farther to 30 cm (which is the customary distance between the computer operator's body and the screen), the strength can hardly be measured. In addition, the electromagnetic waves in space is indeed ubiquitous, but in general, the intensity of this electromagnetic radiation is very small, will not cause harm to human health.

The hazards of radiation.

Computer radiation causes hair loss

Radiation is not the number one factor leading to hair loss. Computer use too long is the key to hair loss: a high degree of concentration on the use of computers, too long brain excitement will increase, endocrine disruption, and hair follicles connected to the sebaceous glands secretion of excessive events leading to hair follicle embolism, hair nutrient supply obstacles, hair will become brittle, hair will fall off. For minor hair loss, you can reduce the time of computer use and adjust your lifestyle to relieve.

Eye damage.

These "unsuitable light" continued exposure to our eyes, will cause dysfunction, especially LED lights, computer screens and other light, which contains a large number of irregular frequency of high-energy short-wave blue light, these short-wave blue light has very high energy, can penetrate the lens directly to the retina. Blue light exposure to the retina will produce free radicals, and these free radicals will lead to the decay of the retinal pigment epithelial cells, the decay of epithelial cells will lead to a lack of nutrients for photosensitive cells and thus cause vision damage.

Radiation avoidance methods.

1. Avoid long periods of continuous operation of the computer, pay attention to the 0intermediate rest. To maintain an optimal posture, the distance between the eyes and the screen should be in 40-50 cm, so that the eyes flat or mildly downward looking at the fluorescent screen.

2. Research has found that radiation from computers can affect the development of the fetus and can cause serious fetal malformations. Indoor to maintain a good working environment, such as a comfortable temperature, clean air, the appropriate concentration of anions and ozone concentration, etc..

3. Computer room light should be appropriate, not too bright or too dark, to avoid direct light on the fluorescent screen and produce interference light. The workroom should be kept ventilated and dry.

4. The computer's fluorescent screen should use color filters to reduce visual fatigue. Preferably use glass or high-quality plastic filters.

5. Computer placement is important. Try not to let the back of the screen towards someone's place, because the strongest computer radiation is the back, followed by the left and right sides, the front of the screen and the weakest radiation.

When using the computer, to adjust the screen brightness, generally speaking, the greater the screen brightness, the stronger electromagnetic radiation, and vice versa, the smaller. However, it can not be adjusted too dark, so as not to affect the effect of too little brightness, and easy to cause eye fatigue.

5.3 Work with electrical equipment

The use of electronic equipment is an indispensable part of the aviation industry, in contact with electronic equipment has to consider is the contact with the energized equipment, in contact with the energized equipment must pay attention to their own safety, including compliance with safety guidelines for the correct installation and use of these devices. Also ensure that in the event of breakage of energized equipment to use insulating materials to contact, to ensure that the body does not produce electric shock phenomenon. Not to touch the lack of leakage protection equipment, when found that the temperature of some equipment is too high in time to check the work of electronic equipment, the use of standard practices to ensure their own safety, check whether it is working properly, whether the work of abnormalities. At the same time should pay attention to the sound issued by the electronic equipment is normal, if found that the electronic equipment produced an abnormal sound should promptly go to check its working status. At the same time, attention should be paid to the use of electronic devices when trying to keep a certain distance from people to ensure that in the event of an accident will not threaten the safety of others.

4.4 Measures to ensure safe working conditions

This paper combines China's laboratory safety management requirements to propose some measures to ensure the safety of the working state.

1. Each laboratory should have a part-time safety officer who is responsible for the safety work of the laboratory. Safety officers should be trained and have certain safety knowledge and skills.

2. The first experimental operation of the personnel must be safety education and training, in mastering the laboratory safety management methods and basic knowledge, familiar with the operating procedures before starting experimental operations.

3. The laboratory should actively promote and popularize general first aid knowledge and skills, such as: burns, trauma, poisoning, electrocution and other first aid treatment. The laboratory should regularly conduct safety inspections, the formation of a system to actively commend the advanced, serious investigation and punishment of accidents.

4. The laboratory in contracting off-campus teaching, scientific research, experimental tasks, should be clear safety responsibilities.

5. The laboratory instruments and equipment, materials, tools and other items should be neatly arranged, reasonable layout. Each laboratory should promptly clean up waste items, not pile up items not related to the work of the laboratory, to ensure

that the safety channel is clear.

6. The laboratory to strengthen the safety of electricity management, no unauthorized modifications, disassembly and repair of electrical facilities; do not pull the wires, the laboratory shall not have bare wire; power switch box shall not be stacked items to avoid electrocution or burning; the use of high-voltage power electricity, should wear insulated rubber shoes and gloves, or with a safety bar operation; someone electrocuted, should immediately cut off the power, or use insulated objects to separate the wire from the body after Then implement rescue.

7. The laboratory in the use of flammable, explosive, highly toxic and bacterial vaccines and other hazardous materials, to be used and stored in strict accordance with relevant management regulations, while having reliable safety precautions, and make detailed records.

8. The laboratory in the use of radioactive materials should avoid radioactive substances into the body and contamination of the body; minimize the measurement of external radiation received by the human body; minimize the harm caused by the proliferation of radioactive substances; radioactive waste to be stored in a special dirt cylinder and regular treatment in accordance with the provisions.

9. The laboratory in relation to pressure vessels, electrical, welding, vibration, noise, high temperature, high pressure, radiation, bright light flashes, bacteria vaccines and radioactive substances in the operation and experiment, to strictly develop relevant operating procedures, the implementation of appropriate labor protection measures.

10. The laboratory for environmental safety management should have a full understanding of the exhaust gas, waste, waste liquid treatment shall be strictly in accordance with the relevant provisions of the implementation, shall not be discharged at will, shall not pollute the environment. New construction and expansion of the laboratory shall be hazardous substances, toxic gas treatment program included in the construction plan.

11. According to the performance requirements of the instruments and equipment, to provide the installation and use of instruments and equipment premises, good water and electricity supply, and should be implemented according to the different circumstances of the instruments and equipment fire, moisture, heat,

frost, dust, shock, anti-magnetic, anti-corrosion, radiation and other technical measures.

12. The laboratory should be regularly maintained, calibrated and calibrated instruments and equipment.

13. Instrumentation failure to organize timely repair, and maintenance records, do not allow their own disassembly.

14. To pay attention to the large instruments and equipment of water and power outage protection, to prevent damage to instruments and equipment due to voltage fluctuations or sudden power and water outages.

15. The safety of equipment to be responsible for the work of the instrument, the management of the instrument and equipment is the safety of the instrument and equipment responsible.

16. Personal use or borrowing and personal custody of instruments and equipment (such as laptops, etc.), the recipient or borrower should be properly stored to avoid damage or loss.

5.5 Fire Safety

This paper uses a computer simulation, which will bring a large computational load to the computer due to the large amount of calculations, making the temperature of the computer itself in a high state, it is very necessary to propose an emergency treatment plan when a laboratory fire occurs. This has a very positive effect on fire extinguishing as well as escape in emergency situations.

Fire accidents are universal and can occur in almost any laboratory. The direct causes of such accidents are:

1. Forgetting to turn off the power supply, resulting in equipment or electrical appliances energized for too long, the temperature is too high, causing a fire.

2. Power supply lines aging, overload operation, resulting in line heating, causing a fire.

3. Careless operation or improper storage of flammable and explosive substances, so that the source of fire contact with flammable substances, causing a fire.

4. Littering cigarette butts, contact with flammable substances, causing a fire.

In the face of fire, we must be familiar with the location of fire extinguishers so that they can be accessed in a timely manner, but also must be the following kinds of awareness:

1. In combustible liquids on fire, should immediately take away all combustible materials in the area of fire, close the ventilator to prevent the expansion of combustion.

2. Alcohol and other water-soluble liquids on fire, you can use water to put out the fire.

3. Gasoline, ether, toluene and other organic solvents on fire, the application of asbestos cloth or dry sand to extinguish. Absolutely no water, otherwise it will expand the burning area.

4. Metal potassium, sodium or lithium fire, absolutely not: water, foam fire extinguishers, carbon dioxide, carbon tetrachloride, etc., available dry sand, graphite powder to extinguish.

5. Note that electrical equipment such as wires on fire, can not use water and carbon dioxide extinguishers (foam extinguishers) to avoid electrocution. Should first cut off the power, and then use carbon dioxide or carbon tetrachloride fire extinguishers.

6. When the clothes on fire, do not run, should immediately use asbestos cloth or thick coat cover extinguished, or quickly take off clothes, the fire is larger, should lie down and roll to extinguish the flame

7. It is found that the oven has an odor or smoke, you should quickly cut off the power supply, so that it slowly cool down, and prepare a fire extinguisher spare. Do not rush to open the door of the oven, so as not to suddenly supply air to fuel the combustion (explosion), causing a fire.

8. In the event of a fire should pay attention to protect the scene. Larger fire accidents should be immediately reported to the police. If there are serious injuries, should be immediately sent to the hospital

9. Familiar with the location of fire extinguishing equipment in the laboratory and the use of fire extinguishers.

In addition, you should be familiar with the location of the safety exits in the laboratory, and when the fire cannot be extinguished, try to use the safety exits to escape, avoid taking the elevator to escape, and move to an open outdoor location.

Conclusion to part 5

In this chapter, we have analyzed the safety of the experimental equipment used in the completion of this thesis and the experimental equipment, and proposed measures to help protect the human body according to the environment, including the norms for the use of electronic equipment, the matters that should be paid attention to when using electronic equipment, the hazards to the human body in the process of using electronic equipment and the possible risk factors. The corresponding analysis is made, and the methods of safe and standardized use of electronic equipment are proposed in the process of completing this paper. At the same time, we propose some measures to protect the experimental environment and students by combining the requirements of labor protection in China. Finally, we analyze the emergency disposal methods in case of fire accidents around labor protection, and use different classifications of suitable fire extinguishers to extinguish the fire when we can ensure that the fire is put out in accordance with the regulations, and escape through the safety exit in time when the fire is large.

PART 6. ENVIRONMENT PROTECTION

6.1 ICAO requirement towards aircraft engine emission

6.1.1 Air traffic development and serious carbon emission problems

The world is facing great environmental problems, such as rising sea levels and deteriorating air quality, etc. In China, also facing serious environmental protection problems, the Chinese government has introduced many relevant measures to limit the emission of harmful gases in civil aviation, thus making people's living environment better. Global air traffic activities maintain a continuous and rapid growth, and while air transportation is convenient for public travel, it also has a serious impact on the global and regional environment, mainly in terms of CO2 emissions during aircraft flight and noise impact around airports during the takeoff and landing phases. Statistics show that carbon emissions from civil aviation transport flights account for about 2% of the total carbon emissions from human activities, making it the fastest growing emitter of greenhouse gases. With the further growth of flight volume, the total GHG emissions still have the tendency to increase further.

On July 21, 2016, the World Meteorological Organization (WMO) released the bulletin "Global Climate Breaks New Records in 20161-June" that global climate indicators have once again set new records. Evidence suggests that the Earth's ecosystems and climate system may have reached or even breached important tipping points that could lead to irreversible changes, with extreme weather such as high temperatures, fog and strong thunderstorms occurring frequently. These weather extremes in turn cause massive flight cancellations and delays, which in turn can affect and constrain the development of the air transportation industry.

The world trend of sustainable development has put forward more stringent requirements for carbon emission of air transportation. In order to cope with the damage to human living environment caused by global warming, the United Nations held the Earth Summit in 1992 and reached the United Nations Framework Convention on Climate Change (UNFCCC), which took the first step to solve this problem, and then proposed the Kyoto Protocol. on November 4, 2016, the Paris

Agreement has officially entered into force. The Paris Agreement is the third landmark international legal text in human history to address climate change, shaping the post-2020 global climate governance landscape. The 175 parties, including China, have jointly committed to reducing greenhouse gas emissions and keeping the global average temperature increase to within 2°C above pre-industrial levels. The Paris Agreement establishes a ratcheting mechanism of "no regression". The action targets set by countries are based on continuous progress, and a binding mechanism is established to periodically assess the effectiveness of countries' actions every five years starting in 2023.

The International Civil Aviation Organization (ICAO), in its comprehensive statement on environmental protection, requires member states to mitigate environmental impacts through optimization of air traffic management. In 2010, ICAO adopted a resolution to improve fuel efficiency in flight to protect the environment at the 37th ICAO Assembly. The long-term goal of improving flight fuel efficiency by 2% per year by 2050 will be achieved, and a medium-term goal of no further growth in net emissions from international aviation from 2020 was proposed.2013 International Air Transport Association (IATA) adopted the Carbon Neutral Growth Program. The program proposes a target for the air transport industry to improve fuel efficiency by 1.5% per annum by 2020.In 2014, the EU set a target to include emissions from the internal segments of the European Economic Area in its emissions trading system by the end of 2016.

Currently, there are three main ways to reduce the environmental impact of air traffic: (1) improving and manufacturing more environmentally friendly engines and aircraft aerodynamic profiles; (2) using bio-alternative fuels; and (3) improving and optimizing the operational quality of air traffic. Given that the current engine and aircraft aerodynamic design technologies are quite mature, the fuel saving potential from the addition of wingtip winglets has been exhausted. The limited raw materials and production of bio-alternative fuels are not sufficient to support large-scale use in air transportation. Therefore, the use of improved and optimized air traffic management operational quality to improve the efficiency of available airspace utilization and flight track fuel efficiency has great potential in civil aviation energy saving and emission reduction.

The Special Plan for Energy Saving and Emission Reduction in Civil Aviation Air Traffic Management System [34 developed by the Air Traffic Management Bureau of the Civil Aviation Administration in 2015, proposes to achieve, with 2015 as the base year, by 2020: a 1% increase in ATM (ATM, Air Traffic Management) operational efficiency, a 3% reduction in average flight fuel associated with ATM, a 3 percent reduction in average flight delay time after closing the doors at busy airports minutes, an average annual reduction in flight CO2 emissions of about 2.6 million tons and an increase in the number of people affected by noise no more than 2% as specified in the "Environmental Standards for Aircraft Noise around Airports". However, a systematic quantitative index system and measurement standards are not proposed.

ATC operation energy saving and emission reduction index system is an important tool to reflect the operational efficiency and effectiveness of ATC green development. On the one hand, it can scientifically, accurately, and objectively show the total fuel consumption and carbon dioxide emissions of aircraft in different flight phases, and clarify the relationship definition and impact degree of flight delays caused by airports, airlines and air traffic control, and also lay the foundation for fair assessment and incentive for the industry. Secondly, it can accurately reflect the utilization efficiency of civil aviation airspace, the operational efficiency of air traffic management, and the effect on the environment, which helps ATC to find out the shortcomings, clarify the focus points, improve the technology, and make precise efforts. Thirdly, it helps to scientifically assess the contribution of various management and technical improvements to civil aviation energy saving and emission reduction. Third, air traffic management energy saving and emission reduction key performance areas and index measurement methods

Through extensive research, combined with the actual air traffic control operation, this paper divides the key performance areas of air traffic management energy saving and emission reduction into four areas: carbon emissions, environmental efficiency, operational efficiency, and noise impact. The calculation of all indicators should take individual flights as the basic research object, and when many flights need to be evaluated as a whole, the corresponding indicator measurement values of the relevant flights can be added up.

6.1.2 Introduction of engine pollution to the environment

Current ICAO Standards for emission certification of aircraft engines are contained HC, CO, NOx, and smoke. Concern about local air quality (LAQ) in the vicinity of airports focus on the effects of emissions released below 3000 feet.

As showed in the Fig.6.1The ICAO adopted its first smoke, fuel venting and gaseous emissions from turbojet and turbofan engines in 1981.

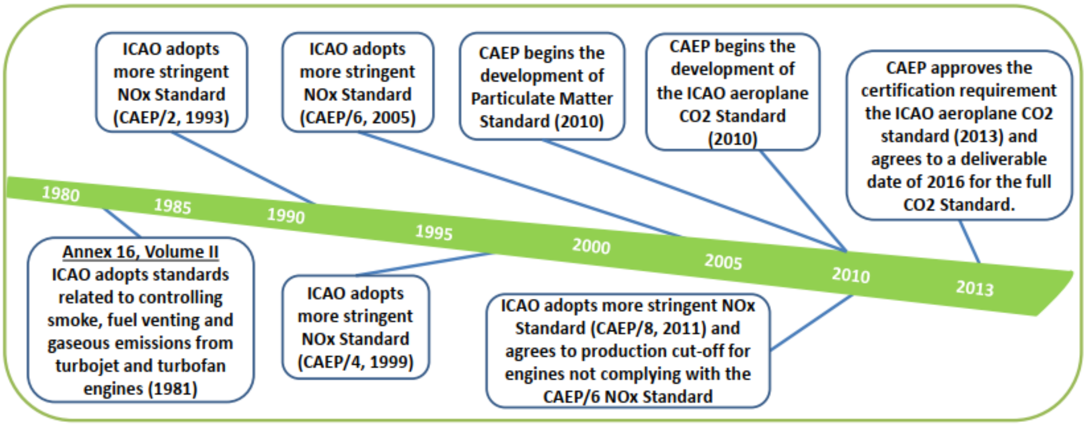


Fig.6.1 - ICAO adopted its first smoke, fuel venting and gaseous emission

The engine emission certification procedure is based on the landing take-off (LTO) cycle, including take-off (100% available thrust) for 0.7 minutes, climb (85% available thrust) for 2.2 minutes, Approach (30% available thrust) for 4 minutes, taxi (7% available thrust) for 26 minutes, the certification process involves running the engine on a test bed at each thrust setting.

6.2 The impact of new design layout on environmental protection

6.2.1 Measures to protect the environment

Air transportation has become the fastest-growing sector in the world in terms of greenhouse gas emissions. The carbon emissions generated by air transportation have constrained the development of air transportation while causing global climate change. In order to achieve sustainable development of air transportation, the international community and our government have developed policies and measures to actively save energy and reduce emissions. After improving engines and bio-alternative fuels, the optimization of air traffic management is an important grasp to tap into energy saving and emission reduction in civil aviation. In this paper, with the starting point of discovering the shortcomings of ATC operation and improving the performance of ATC operation, fuel consumption, fuel efficiency, operational efficiency and conducted research

Fast take-off and landing, reducing the impact time of the aircraft on the surrounding environment has a positive effect on environment.

The airspace system is becoming increasingly congested as the number of aircraft operations grows to meet passenger and goods demands. The bulk of traffic contributes to airport traffic saturation. Due to this increase, populations living near airports, as well as the environment, are impacted by commercial aircraft.

Conclusion to part 6

This diploma work will carry out scientific research and engineering progress in accordance with some policies of environmental protection. This saves unnecessary fuel consumption to increase thrust, saves fuel and reduces CO^2 emissions, which is very beneficial to the environment. The shorter take-off and landing distances help to reduce engine pollutant emissions and reduce the impact of noise disturbances on the surrounding environment during take-off and landing.

The airplane saves unnecessary fuel consumption to increase the thrust, saves fuel and reduces the emission of CO^2, which is very beneficial to environmental protection. The shortened takeoff and landing distances help reduce the emission of engine pollutants and reduce the impact of noise disturbance during takeoff and landing on the surrounding environment.

GENERAL CONCLUSION

To achieve design goals, the following objectives where solved:

(1) First, analyze and summarize the existing launch system, analyze, and summarize from the principle, structure, reliability, cost and use, and finally design the launch system powered by the motor propeller.

(2) Using FLUENT fluid mechanics simulation software to estimate the aerodynamic parameters of the UAV.

(3) The UAV launch system is designed and its feasibility and reliability are verified.

(4) After the structural design verification and statics simulation of the UAV launch system, the dynamic simulation of the launch process is carried out in combination with the aerodynamic parameters of the UAV.

(5) For the Labor protection, proposing some measures to protect the experimental environment and students by combining the requirements of labor protection in China. Finally, analyze the emergency disposal methods in case of fire accidents around labor protection, and use different classifications of suitable fire extinguishers to extinguish the fire when we can ensure that the fire is put out in accordance with the regulations, and escape through the safety exit in time when the fire is large.

(6) For the environment protection, Launchers and UAVs mentioned in the paper will carry out scientific research and engineering progress in accordance with some policies of environmental protection, to saves fuel and reduces the emission of CO2, which is very beneficial to environmental protection. The shortened takeoff and landing distances help reduce the emission of engine pollutants and reduce the impact of noise disturbance during takeoff and landing on the surrounding environment.

Reference

1.Dordrecht. Handbook of unmanned aerial vehicles[M]. Netherlands, Springer, 2015.

2.鲁亚飞，陈清阳，王鹏，等．小型固定翼无人机精确回收技术发展与关键技术分析[J].飞航导弹,2020(04):59-65.

3.朱超磊，袁成，杨佳会，康国卫. 2021 年国外军用无人机装备技术发展综述 [J/OL]. 战术导弹技术：1-8[2022-02-23]. http://kns.cnki.net/kcms/detail/11.1771.TJ.20220211.1110.001.html.

4.Chen S, F Laefer D, Mangina E. State of technology review of civilian UAVs[J]. Recent Patents on Engineering, 2016, 10(3):160-174.

5.Gupta S G, Ghonge D, Jawandhiya P M. Review of unmanned aircraft system (UAS)[J]. International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) Volume, 2013, 2.

6.Valavanis, Kimon P., and George J. Vachtsevanos, eds. Handbook of unmanned aerial vehicles. Vol. 1. Dordrecht: Springer Netherlands, 2015.

7.我国无人机行业发展现状与前景分析[J].军民两用技术与产品,2020(07):10-19.

8.Crowther W J. Perched landing and takeoff for fixed wing UAVs[C]//NATO symposium on unmanned vehicles for aerial, ground, and naval military operations. 2000: 9-13.

9.Skulstad R, Syversen C, Merz M, et al. Autonomous net recovery of fixed-wing UAV with single-frequency carrier-phase differential GNSS[J]. IEEE Aerospace and Electronic Systems Magazine, 2015, 30(5): 18-27.

10.叶帅辰，姚晓先．无人机自力起飞方式研究[J].火力与指挥控制,2019,44(04):6-11.

11.杜聪聪，李武军，陈朝浪，马明旭．固定翼无人机回收与发射系统发展综述[J]．科技传播, 2016,8(07):113-115.

12.Li K, Chen G. Analysis of Parachute Recovery Process for UAV based on Launch Rocket[C]//IOP Conference Series: Materials Science and Engineering. IOP Publishing, 2019, 569(3): 032066.

13.鲍传美，刘长亮，孙烨，王宏新．无人机发射技术及其发展[J]. 飞航导弹, 2012(02): 56-60.

14.胡明，刘高，梁振刚．小型无人机弹射系统的动力学研究[J]. 成组技术与生产现代化, 2017, 34(03): 6-9+13.

15.Skitmore A. Launch and Recovery System for Improved Fixed-Wing UAV Deployment in Complex Environments[M]//Unmanned Aerial Remote Sensing. CRC Press, 2020: 303-316.

16.卢伟，马晓平，周明，杨会涛．无人机气动弹射动力学仿真与优化[J]．西北工业大学学报, 2014,32(06):865-871.

17.Hanyok L W, Smith T C. Launch and Recovery System Literature Review[J]. 2010.

18.苏子舟，张博，国伟，刘学超，屈武斌．无人机电磁弹射应用综述[J]．火炮发射与控制学报, 2011(01):93-96.

19.Sibilska-Mroziewicz A, Ładyżyńska-Kozdraś E, Falkowski K. Modelling of Forces Acting on a System of the UAV Launcher, Based on Passive Magnetic Suspensions with Superconductors[J]. NAŠE MORE: znanstveni časopis za more i pomorstvo, 2020, 67(1): 60-68.

20.浦广益.ANSYS WORKBENCH 基础教程与实例详解[M].北京:中国水利水电出版社,2018.12

21.高永,孟浩,李冰,王玉伟.基于 Simulink 的小型无人机弹射架性能仿真[J].海军航空工程学院学报,2017,32(05):452-456.

22.Chinese Labor Protection Law.

23. European Union Health and Safety Legislation website.

24.International Finance Corporation. 2007.General EHS Guidelines-Occupational Health and Safety.

25.International Labor Organization SafeWork website.

26.Guidelines on occupational safety and health management systems.

27.International Organization for Standardization. 2018.Occupational health and safety management systems .

28.National Institute for Occupational Safety and Health.

29.Peking University Laboratory Requirements.

30.Aviation Emission, Impacts& Mitigation: A Primer; Office of Environment and Energy, January 2015

31.Paris Agreement to lead global "decarbonization" development. Xinhua [DB/OL]

32.ICAO,ResolutionA3719:ConsolidatedstatementofcontinuingICAOpoliciesandpracticesrelatedtoenvironmentalprotectionClimatechange[DB/OL]

33.IATA. IATA Fuel Reporting & Emissions Database(FRED).

34.Civil Aviation Authority. Opinions on Further Deepening Civil Aviation Reform Efforts. [S] (Civil Aviation Development [2016] No. 40)

35.Civil Aviation Administration Air Traffic Control Bureau. Special Plan for Energy Saving and Emission Reduction in Civil Aviation Air Traffic Control System. [S](ECO-2015),16-17

36.European Comission, Reducing emissions from aviation,[DB/OL]