Design and Manufacturing II project report

A self-righting jumping robot with angle adjustment via flexible rods

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Executive Summary

This project is based on a subject from the project challenge competition--jumping robot.

According to the requirements of the competition, we made the jumping ability our priority. On that basis, we attached self-righting function to it for higher controllability.

After a comprehensive review on some existing jumping robot designs, we decided to use carbon fiber bars to construct the jumping part and realize the self-righting function through four-bar mechanisms.

We manufactured most of the parts with 3D printing and assembled several prototypes. The cost is about 400 yuan for one single prototype.

After some calculations and several tests on the prototypes, we proved the reliability of the design and got an estimated jumping heigh for about 5.8 meters.

In conclusion, our jumping robot can jump to a considerable height, while it can also adjust its position with the self-righting unit and jump in a given direction. However, there are still some weaknesses for this design. For example, it cannot jump continuously. There are also some redundant weights which can affect the performance of the robot. In the future development, we will attach more functions to it and further simplify the structure to perfect its performance.

CONTENT

1. Introduction

This project is based on a subject from the project challenge competition--jumping robot.

First, for a jumping robot, the most important index is the jumping ability. To help achieve an ideal jumping height, the jumping robot should be light and strong. Other criteria about whether a jumping robot is good are controllability (if we want to control its jumping pattern and adjust its jumping direction or body posture, or the robot can be controlled remotely), repeatability (the jumping robot can jump continuously without breaking down physically or procedurally), long-life (the jumping robot won't break up due to falling or other structural problems) and so on. Therefore, we first made our QFD (see appendix A) to identify what engineering specifications we should pay attention to in our design and manufacturing process.

As for the requirements, we give seven indexes of a jumping robot: low price, light weight, controllability, repeatability, high strength, long lifetime and high jumping ability. The top priorities among the characteristics are high jumping ability, light weight and repeatability, for they are the most important standard given by the project challenge. The structure of the jumping robot should also be strong to achieve the goal. Low price and long lifetime are not so important as other indexes.

To achieve the target requirements, we give six engineering design specifications: type of material, energy storage structure, jumping height, total weight, model size and jumping preparation time. Type of material and total weight of all the components are important to light weight, while energy storage structure and preparation time for jumping are important to controllability and repeatability. The type of material is also crucial to the cost, lifetime and strength of our robot. Last of all, for the most important index, jumping ability, we should consider the coordination of all the engineering design specifications, for it is affected by every of them.

The QFD chart we make is shown below:

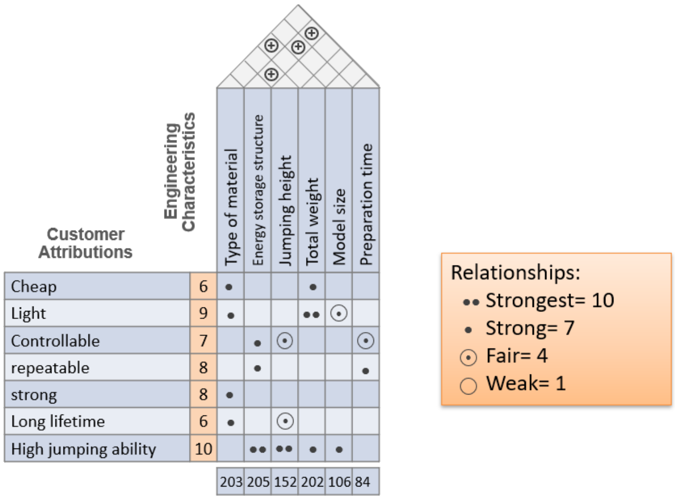


Fig 1.1 QFD Chart

2. Concept Generation and Selection

2.1 Literature Review Methodology

In this project, we reviewed many articles about high-jump robots. All of the review process are done with *Web Of Science* ™. The key words we choose are 'hopping robot', 'jumping robot', 'self-righting'. After reviewing one article we are interested in, we find similar articles from the reference of this article.

Our concept choices are all from the reviewed articles. Concepts we generated are listed as follows.

2.2 Concept Description

2.2.1 Energy Storage Structure

For the energy storage structure used in robots, we have reviewed more than 20 designs and summarize them into a diagram (Fig 2.1):

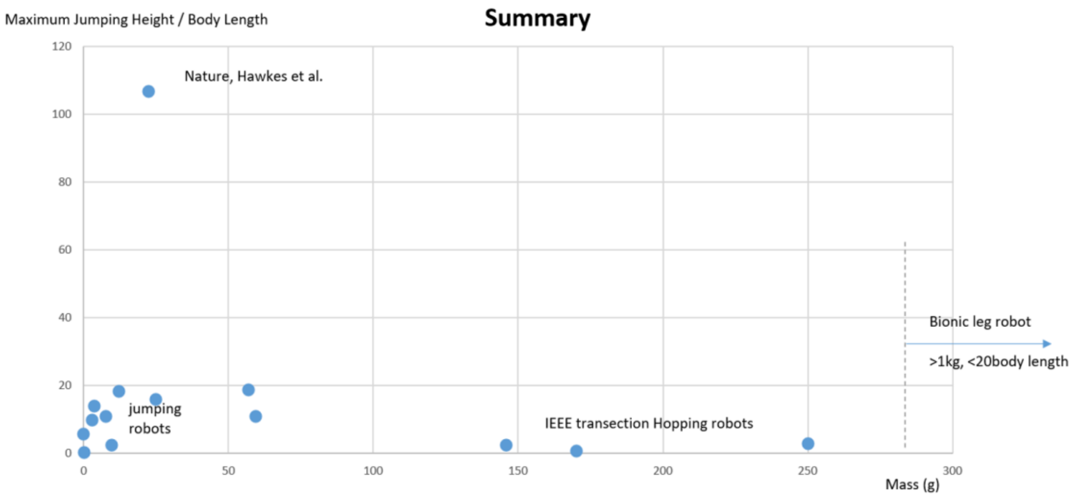


Fig 2.1 Summary of previous jumping robots

Then we categorize them into two groups:

The first group[1]-[8] is what we call 'Bionic legs'. They are more a component than a single robot, like the dog legs on robotic dogs. They consider walking as an important function, which makes their jumping performance not quite satisfactory. They are usually heavy and jumps less than 20 times its body length.

The second group[9]-[19] is 'oddly-shaped' structure. They are usually lighter because they're designed just for jumping. Most of them are MEMS robots (very light and actuated by smart materials). However, most of them can only perform a single jump. Some hopping robots can jump continuously, but thy usually have larger weight and lower jumping height.

2.2.2 Self-righting & Angel Adjustment Mechanism

In this project, we reviewed four self-righting mechanisms for jumping robots.

The first article[20] includes 2 mechanism.

The first mechanism is shown in Fig 2.2(a). This mechanism uses a motor on the bottom to lift its own weight directly.

The second mechanism is in Fig 2.2(b). This design uses a four-bar mechanism with a slider to fold itself and achieve self-righting.

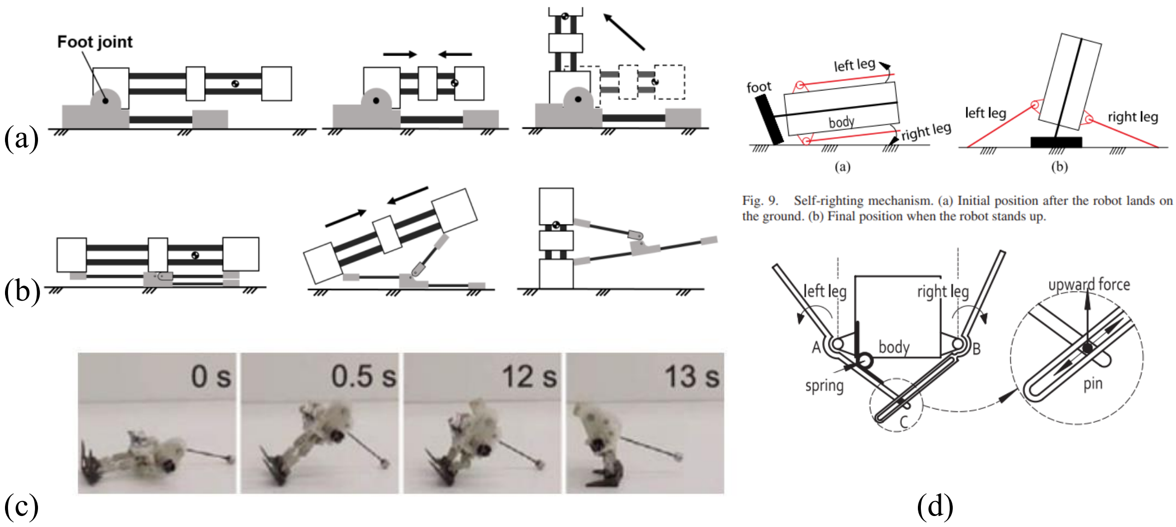


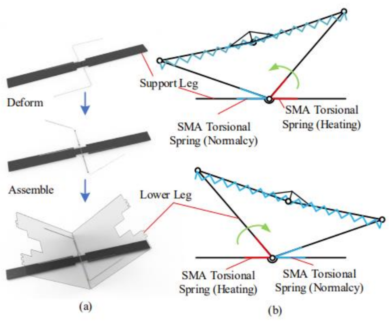
Fig 2.2 Self-righting Mechanism

The second article[22] uses an auxiliary tail to right itself. This process includes relatively complex control compared to other mechanisms.

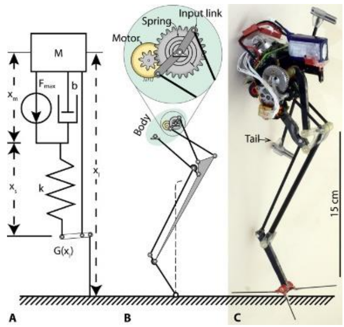
The third article[21] uses auxiliary sticks on its side to support itself. This design of stick motion can make the output torque of the motor smaller than other designs.

2.2.3 Quick-release Mechanism

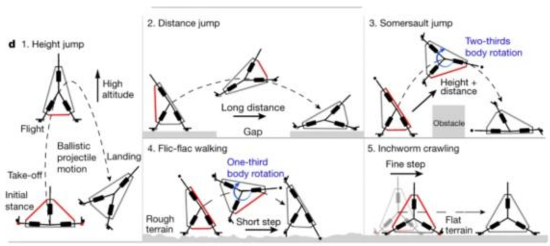
We reviewed the four designs below, as is shown in Fig 2.3:



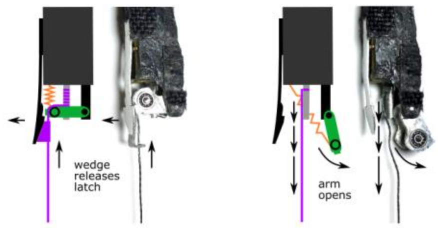
(a)



(b)



(c)



(d)

Fig 2.3 Quick-release Mechanisms

The two designs in (a)[25] and (c)[24] are very similar to each other. By using the change of bars' position, the force of the spring turns from resistant force into actuating force. What's different is that, design (a) uses a rotatable four-bar linkage to achieve angle adjustment, but the design (c) uses the difference between tension forces in each spring to achieve angle adjustment. In this way, the jumping process can be continuous.

The design in (b)[23] also uses the change of position and spring force, but it uses a torsional spring and rotation input-output. It can also perform repeatable jump.

The design (d)[9] is different. It uses an object tied on the string to lift away the elastic material that supports the green part. The green part is used to hold the string on the motor. As the green part falls down, the string is released instantly.

2.3 Concept Choice

2.3.1 Energy Storage Structure

In the previous section, we have discussed about the two categories of jumping robots.

For our project, we need a considerable jumping height to ensure our success in the challenge competition. Thus, the first group is excluded out of our consideration.

Besides, as undergraduates, we are unable to make a controllable MEMS robot, or use soft materials or smart materials to make this robot. Moreover, we need room for further modification since we want to make a robot that have self-righting and angle adjustment function.

Thus, we decided to implement the Nature structure[9]: this structure is actuated by large deflection flexible rods. By using compliant material, it can store large amount of energy. The original article has very good performance. With a weight of 30g, it can jump more than 30m high.

2.3.2 Self-righting Mechanism & Angel Adjustment

As is discussed before, the first design requires large torque and brings in large redundant weight; the second article needs complex control, leading to long adjust time and more works on coding procedure. Thus, they are excluded.

We decide to combine the rest two together: use the compressibility of our robot at the first time, use four bar mechanism and auxiliary sticks to support our robot. That will help us achieve self-righting and angle adjustment at the same time without bringing in too much extra weight.

2.3.3 Quick-release Mechanism

In this part, we think that the first three designs have a much smaller work space than (d). We need a large displacement to achieve large deformation of the rods. Besides, extra mechanisms will bring in extra weight, so we decided to implement concept (d). Though it cannot achieve repeatable jump without human aid, it is lighter and more suitable for our design.

3. Final design

3.1 Final design concept

3.1.1 Energy-store Mechanism

To cooperate with the angle-adjustment mechanism, we used 3 carbon fiber bars to construct the energy storage structure. As is shown in Fig 3.1, the energy required for jumping is mainly stored in three bended carbon bars. The bars are connected to connectors on both ends through rotating joints made of special fabric and 5569 glue.

Fig 3.1 Energy storage Mechanism

The shape of the carbon bars is specially designed (Fig 3.2). The middle of the bar is slightly thinner than the end, which forms a hyperbola curve. This shape enables the bar to bend more easily in the middle and form a "U" shape, which is very useful for self-righting and angle adjustment in the jumping preparation period.

The rotating joints between the connectors and the carbon bars are made of nylon fabric and 5569 glue. If we choose to design a tiny traditional joint mechanism instead, the precision needed for manufacturing is very high and thus unaffordable for our project. To realize the same function with low cost, we decided to use nylon fabric

Fig 3.2 Shape of the carbon bar

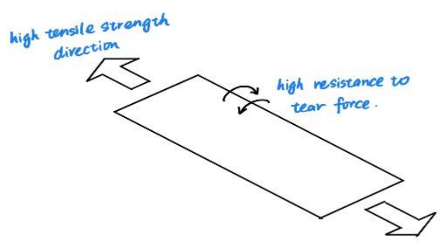


Fig 3.3 Fabric with special characteristics

which has large strength in one direction and high resistance against the tear force in another direction (Fig 3.3).

3.1.2 Instant-release Mechanism

As is shown in Fig 3.4, when the motor starts working, the wire tightens and changes its direction through an axle perpendicular to the shaft, and then gradually coils on the shaft. The wedge fixed to the wire raises as the wire is coiled to the shaft. If the wedge goes into the narrow space between the latch and the axle, the latch will bend and release the arm. At this moment, the wire and the motor shaft are in the same direction, so the wire coiled to the shaft will release fast, which enables the robot to jump.

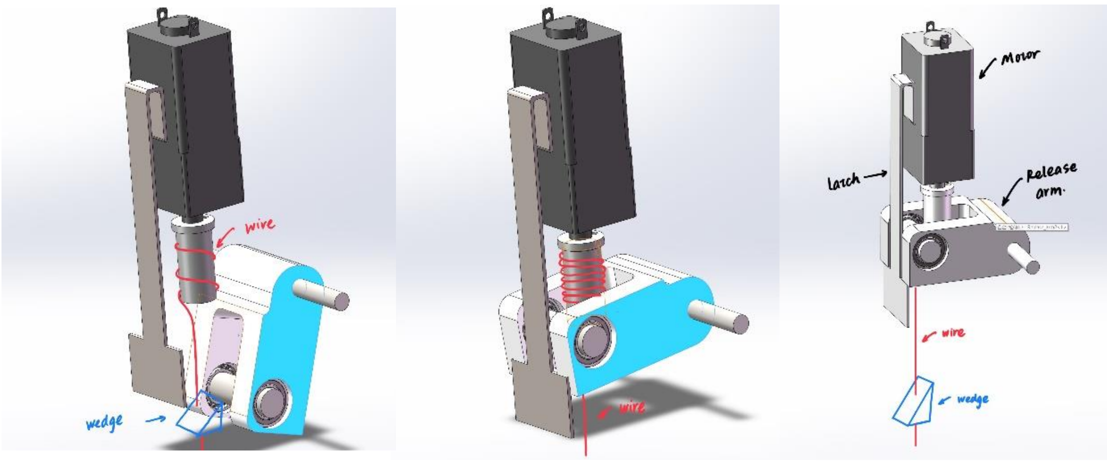


Fig 3.4 The working principle of the instant-release Mechanism

Because the motor we bought only has a bare shaft, we designed a sleeve to connect the wire and the bare shaft. The shape of the sleeve is shown in Fig 3.5, which has two holes. The smaller hole is for tying the wire, and the larger one is designed for interference fit with the shaft.

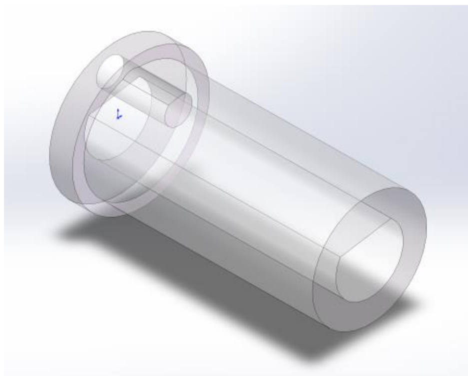


Fig 3.5 The sleeve

The latch is made of spring steel for good elasticity to deform and recover. And the axle through two bearings is used to make the coiling process smoother.

3.1.3Angle-adjustment mechanism

The angle-adjustment mechanism (Fig 3.6) consists of three power screw mechanisms (Fig 3.7). By controlling the rotating direction and speed of the power screw motor, the support foot will change its direction. With three feet cooperating together, the angle adjustment function can be realized.

Fig 3.6 Angle-adjustment Mechanism

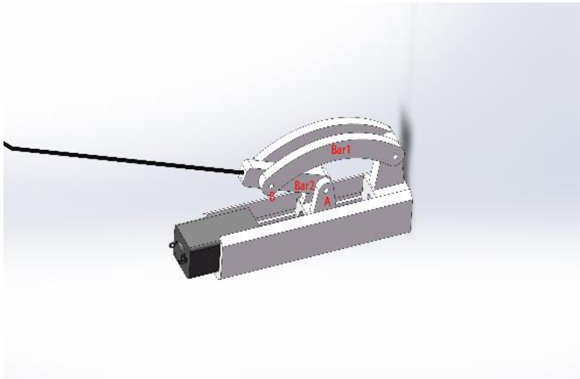


Fig 3.7 Power screw mechanism

When the screw on the motor rotates, the nut fixed in the slider (Fig 3.8) will move forward or backward along the screw. Because the distance between pin A and pin B is fixed, and bar 1 can rotate, so the angle of bar 2 is changed as the slider moves along the slideway. This is an application of four-bar mechanism.

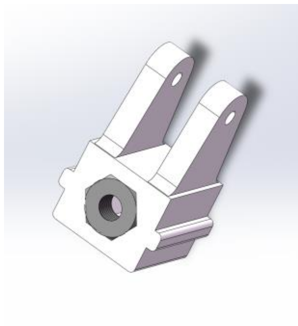


Fig 3.8 Nut in the slider

To decrease the overall weight, we simplified the connection methods between the bars. Instead of using bolts and buts, we decided to use bare axle to connect different parts. According to some tests, we found the bare axle can be constrained by friction and won’t slip out of the hole. This method of connection is proved to be reliable.

3.2 Approaches to determine the specific parameters.

3.2.1 Determination on the motor type

During the early stage of our design process, we tested a prototype of energy-store mechanism with four 1mm-thick carbon bars) and found that the force needed to bend the carbon bar to a specific shape is 21N. In order to increase the stored energy and avoid failing of the carbon bars, we finally decided to choose 3 carbon bars of 1.2mm-thick, and the force we should offer when bending them to the same shape is about $21N \times \frac{3}{4} \times (\frac{1.2mm}{1mm})^3 = 27.22N$. After attaching the sleeve to the shaft of the motor, the radius is $2.5mm$, so the torque required is $53.16N \times 2.5mm = 0.69kg \cdot cm$.

To get ready for jumping in no more than $30s$, the motor must have a minimum rotating speed of $\frac{L}{2\pi rT} = \frac{300mm}{2\pi \times 2.5mm \times 30s} = 38.20rpm$. In consideration of reducing the total weight and fit the voltage output limit of Arduino NANO, we finally chose the motor GA12-N20-6V-50rpm.

3.2.2 Process of reducing weight

Since the lighter the robot, the higher it can jump, we should reduce as much weight of the design as possible.

We divided the robot into two parts, the upper part (mainly the self-righting and angle adjustment unit) and the lower part (mainly the energy storage structure). The weight of the motor is nearly the same as the model built in SolidWorks filled with photosensitive resin. So, for the upper part of the robot, the first version weighs $88g$, according to the mass evaluation module shown in Fig 3.9.

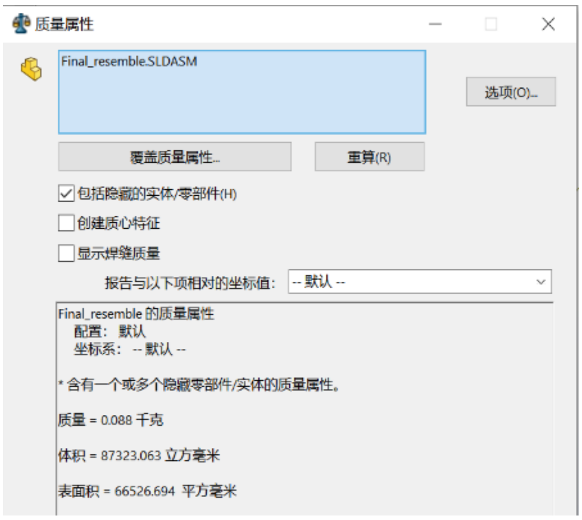


Fig 3.9 Mass of the upper part (first version)

The density of the carbon board is $1.42g/cm^3$, while the voltage of the carbon bars we used $10.8cm^3$, so the weight should be $15.3g$. Taking the weight of string, ballistic nylon, and the control boards into consideration, we can assume the weight of lower part of the robot is $22g$. Thus, the total weight should be $110g$.

To further reduce the weight, we did simulations in SolidWorks in order to exclude some redundant parts. According to the SolidWorks simulation analysis shown in Fig 3.10-3.12, we redesigned these two parts and modified the size of several other parts. Finally, the weight of upper part is decreased to $71g$ (Fig 3.13), so the total weight should be 93g.

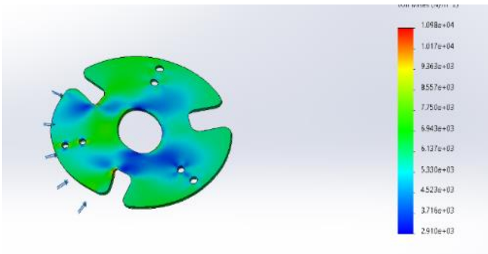


Fig 3.10 Result of simulation1

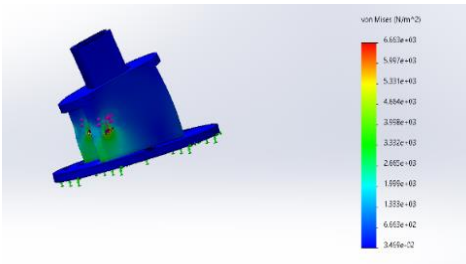


Fig 3.11 Result of simulation2

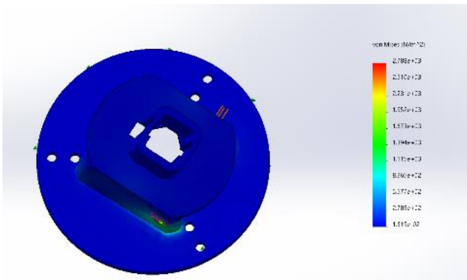


Fig 3.12 Result of simulation3

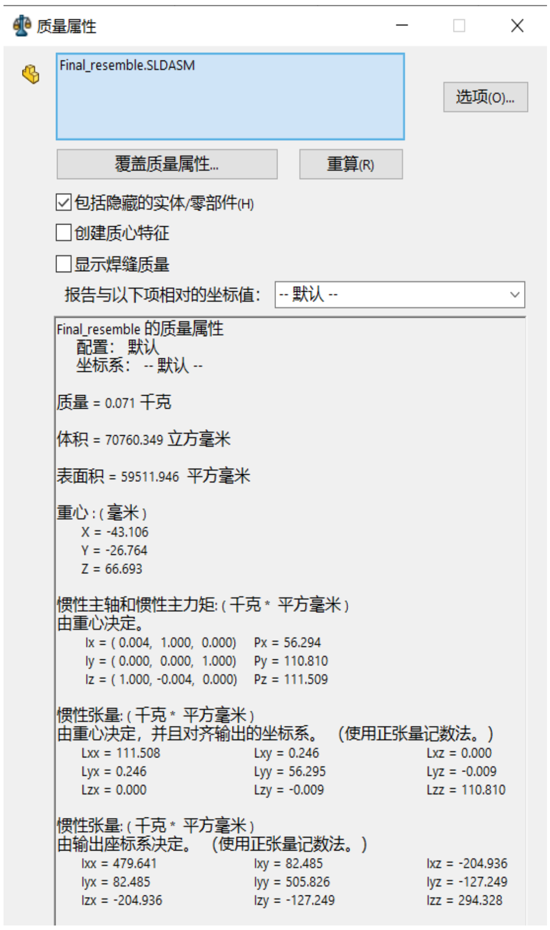


Fig 3.13 Mass of the upper part (second

The prototype in the nature article weighs only 30g, but it doesn't have the ability to adjust angle. We sacrificed the weight in change of more abilities.

3.2.3 Power screw selection

We browsed the TaoBao but only find one mini-motor with power screw of suitable length ($34mm$). To make the full use of the 34mm power screw to realize a wide range of angle adjustment, we experimented several times on the lengths of the two bars according to the angle adjustment animations in SolidWorks, and the size we finally used can be measured from the 3D model. To validate the choice of the size, we made some calculation as follows:

The motor: $\omega = 48rpm = 1.6\pi\, s^{-1}$;

Torque $T = 1\, kg \cdot cm = 0.1\, N \cdot m$;

The screw: Lead $l = 0.5mm$; $\alpha = 30°$; The mean diameter d_m is a little bit less than $3mm$.

Assume $f = 0.06$, then the maximum force on a screw:

$$F = \frac{2T}{f_c d_c + d_m(\frac{l + \pi f d_m sec\alpha}{\pi d_m - f l sec\alpha})}$$

$$= \frac{0.2}{0.06 \times 0.003 + 0.003(\frac{0.0005 + 3.14 \times 0.06 \times 0.003 \times 1.16}{3.14 \times 0.003 - 0.005 \times 0.06 \times 1.16})}$$

$$= 1.8874N$$

Let the safety coefficient $N = 5$, and contact screw number to be 10, we have:

$$F_{max} = \frac{10F}{N} = 3.77N$$

The calculation of the self-righting mechanism is shown in Fig 3.14:

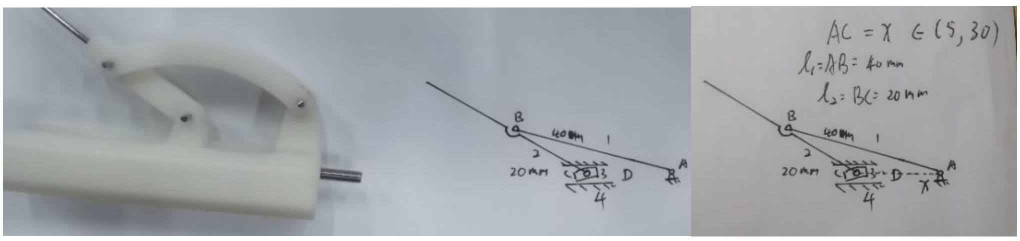


Fig 3.14 Calculation of the self-righting Mechanism-1

When lifting up the body, Assume the initial state is lying with 2-feet on the ground (each bears about half of the weight). Then we get the condition in Fig 3.15:

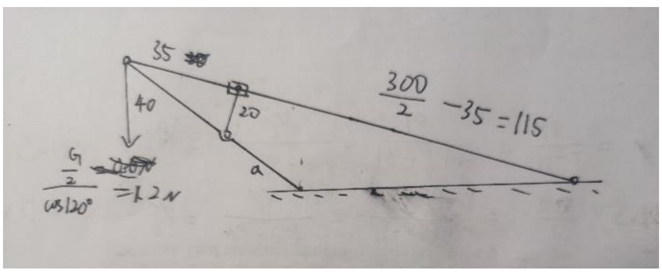


Fig 3.15 Calculation of the self-righting Mechanism-2

The calculation of the screw is shown in Fig 3.16.

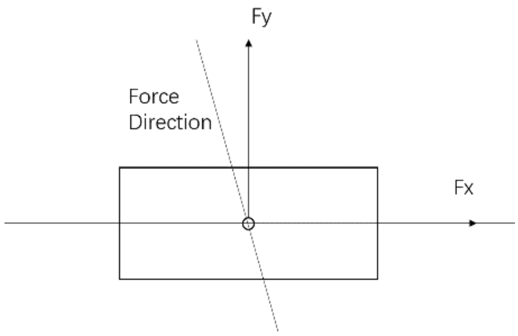


Fig 3.16 Calculation of the screw

If we want the force on the screw to be safe, for the screw part, decide the value a.

$$F_x < 3.77N$$

Thus, $F < 56 \times F_x = 211N$. F has a large range of tolerance (which is larger than the tolerance of the material and the possible force attached on these parts).

Regardless of the value a, we can lift the whole mechanism up if the material allows.

3.2.4 Selection of the carbon bar thickness

During the early stage of design, we bought 0.8mm and 1.0mm-thick bars for tests, and we found both of them can be bended to a "U" shape, which meets our need. To increase the energy stored in order to jump higher, we chose the 1.0mm thick bar to make the prototype and did some experiments. Through the tests, we found that this prototype can provide about 21N force. In consideration of the extra weight due to the angle-adjustment and other controlling parts, we decided to try thicker bars for larger energy storage. We bought 1.4mm bars, but we discovered signs of cracking during the bending test. Finally, we tried 1.2mm-thick bars and found it suitable.

3.3 Design for manufacturability and assembly.

To minimize the total weight, maximize the jumping height and simplify the assembling process for testing, we decided to design our project as a one-of-kind object.

We modularized different function parts, including instant-release part, energy-storage part and angle-adjustment part, for convenient substitution and experiment. Thus, instead of waiting for the whole mechanism to be designed, we can validate and optimize each part individually.

To connect these three parts reliably and reinforce the rotating joint on the end of the carbon bar, we decided to connect them by nut and bolt instead of just glue them together. Therefore, we designed special assemble method to connect these three compact parts, as is shown in Fig 3.17.

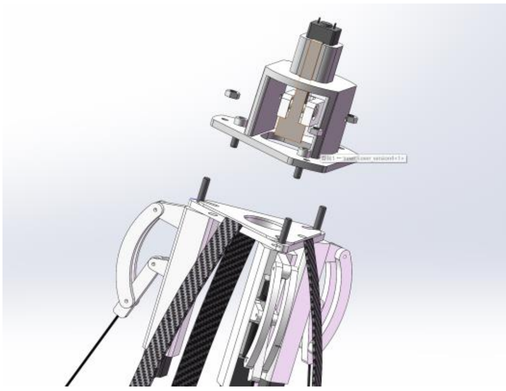


Fig 3.17 Special assemble process

Three bolts on the down part are fastened by nuts, which assemble the upper part and the down part together reliably. Three bolts on the upper part are for locating the angle adjustment mechanism, avoiding them to rotate. By this assembly method, we can see from Fig 3.18 that the rotating joint at the end of the carbon bar is reinforced again, decreasing the possibility of fabric failure.

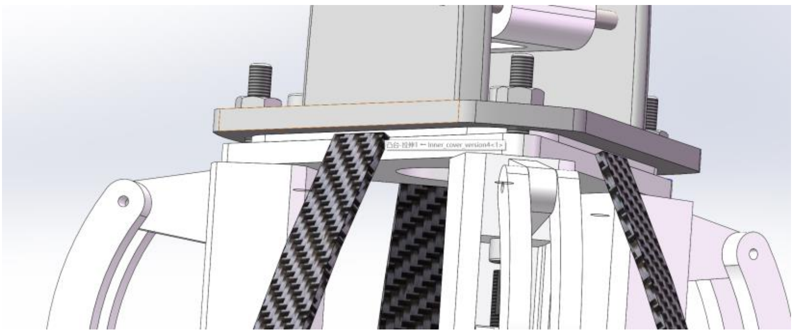


Fig 3.18 Rotating joints are reinforced

During the process of design, we considered many other details for the convenience of assembling. For example, we designed two grooves in the fixing position of motor. One is for the power wire and the other is for the connection of latch. Because the latch only deforms in the direction perpendicular to the wide face, the shape of latch is carefully designed, by which we just need to clamp the latch to the groove without any

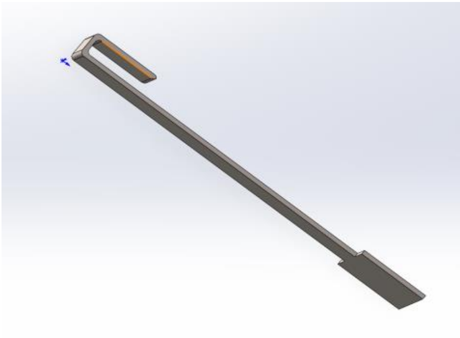


Fig 3.19 Shape of latch

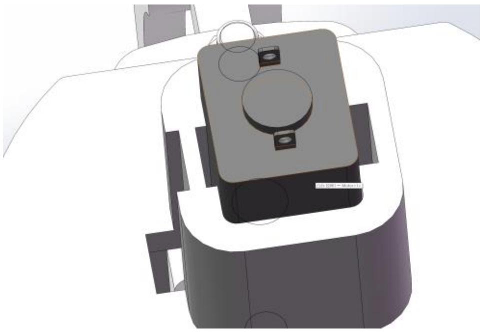


Fig 3.20 Two specially designed grooves

nails (see Fig 3.19-3.20).

3.4 Fabrication plan

3.4.1 Part Material and Manufacturing

Most of the parts we designed are made of 3D printing materials (Fig 3.21-a).

(a)

(b)

Fig 3.21 (a) 3Dprinting parts; (b) Flexible rods;

In this work, we need to make these parts as light as possible. But it's hard to manufacture these odd-shaped part by machining. So, 3D printing is the most feasible choice. Besides, we chose photosensitive resin as the 3D printing material. This kind of material has higher strength compared to others thus the parts are able to resist the impact when the mechanism falls down onto the ground. It also has a relatively lower price so that we can save some costs. For mass manufacture, we can use special plastics to further reduce the cost.

The three limbs in the lower part are carbon fiber bars (cut down from a carbon fiber board) (Fig 3.21-b). Carbon rods are flexible and of great strength, which can store a considerable amount of energy and release them in a short period of time. Furthermore, we use glue 5569 since it is a commonly used glue for carbon materials.

We chose ballistic nylon strips as connecters for the carbon fiber bars. It has great performance in resisting tensile stress and elongation. The strips are cut down from a whole piece of nylon cloth and should be made into a specific shape so that we can easier glue them together with the carbon fiber bars. We first printed the desired shape on a piece of A4 sheet and pile the cloth on it. Then we use scissors to cut the cloth according to the shape on the paper. In real production, high accuracy cutting machines are suitable for these jobs.

Other parts in the electronic system are listed in the Parts List.

3.4.2 Fabrication Process

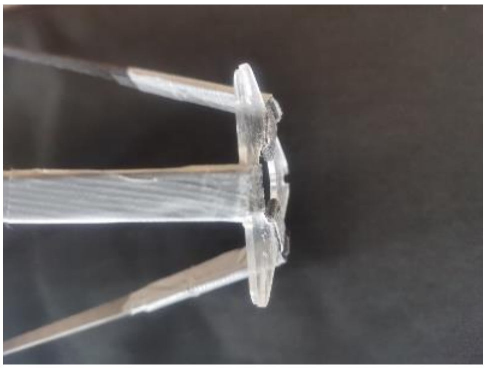
For the upper part, we first assembled the three self-righting units. Each of them is a four-bar linkage. We used steel axes as the linkage. Then we installed them onto the frame with screws. The auto-releasing unit was installed with some bearings and another steel axis (Fig 3.22).

Fig 3.22 Typical steel axis linkage and the whole upper part;

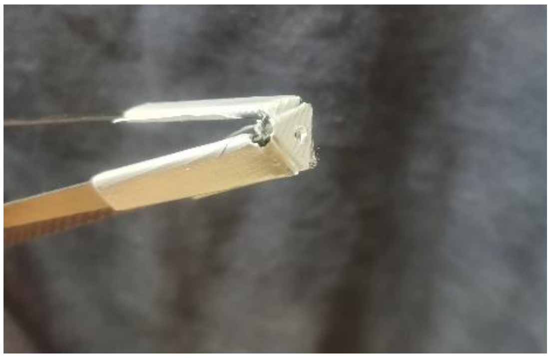
After the upper part was assembled, we connected the carbon fiber bars to it with the nylon strips and glued them together. The bars were glued beneath the nylon strips thus it won't tear off from the strips when they bend. The nylon strips can form hinge-like structures. Traditional hinges are too heavy for a jumping robot. They may also excessively restrict the movement of the carbon fiber bars since they are rigid parts, which can influence the energy releasing efficiency. So, a light and soft hinge made of nylon cloth is ideal. Besides, the joints between the carbon fiber bars and the nylon strips were wrapped with industrial tapes. Instead of being uniform in width, the carbon fiber bars are wider at both ends and thinner in the middle. So, they can be wrapped tightly with tapes without sliding. It can effectively reinforce the joints between the carbon fiber bars and the nylon strips (Fig 3.23-a).

The bottom part consists of a small triangular piece with a small hole in the middle. It was connected with the carbon fiber bars in the same way (Fig 3.23-b). A thread went through the hole, with a small stick tied at the other end serving as a clip. The thread was tied to the motor shaft. When the motor operates, the thread will wrap around the shaft. The other end will pull the bottom part and bend the carbon fiber bars.

Actually, gluing the carbon fiber bars and the nylon strips isn't the best way to fix them up. In real production, we can drill tiny holes on the bars and nylon strips and screw them together, which is nice and secure.



(a)

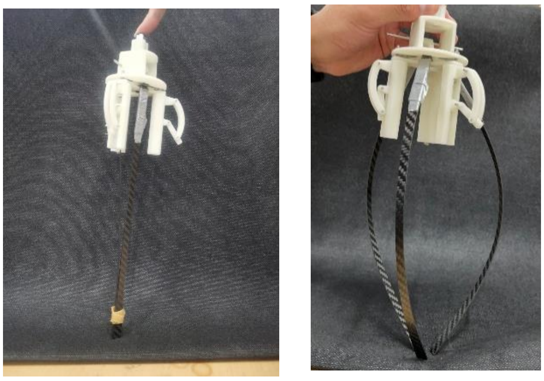


(b)

Fig 3.23 (a) The hinge linkage in the upper part;

(b) The hinge linkage in the lower part;

Then we get the final prototype, as is shown in Fig 3.24.



(a) (b)

Fig 3.24 (a) The fabricated prototype; (b) The prototype bending performance;

4. Test results

4.1 Engineering characteristics analysis

We chose some engineering characteristics from the QFD to discuss (Fig 4.1).

Engineering Characteristics
Type of material
Energy storage structure
Jumping height
Total weight
Model size
Preparation time

Fig 4.1 Engineering characteristics

We have already discussed the energy storage structure, the total weight and the preparation time in the final system design section. They are carbon fiber elastic energy storage mechanism, 93g, and less than 30s respectively. This means that our design meets the requirements of lightness, controllability and good strength.

For the analysis of jump height, we designed separate tests.

4.2 Test design

To validate the effectiveness of our work, we designed several tests. First, we tested the elasticity of the three 0.8mm thick carbon plates in the lower part of the robot to predict the jumping height. We connected one end of a thin wire to the bottom of the mechanism and the other end to a dynamometer after passing through the head of the mechanism and marked the reference point. The force gauge was pulled and the displacement of the reference point and the corresponding magnitude of the pulling force were recorded. In this way, we can obtain the ideal elastic potential energy of the mechanism. It is:

$$E = \int F\,dx \;=\; the\ area\ inclosed\ by\ the\ curve$$

4.3 Test results

We measured the force every 1cm until the carbon bars reached the maximum bending point, and we got the data shown in Fig 4.2：

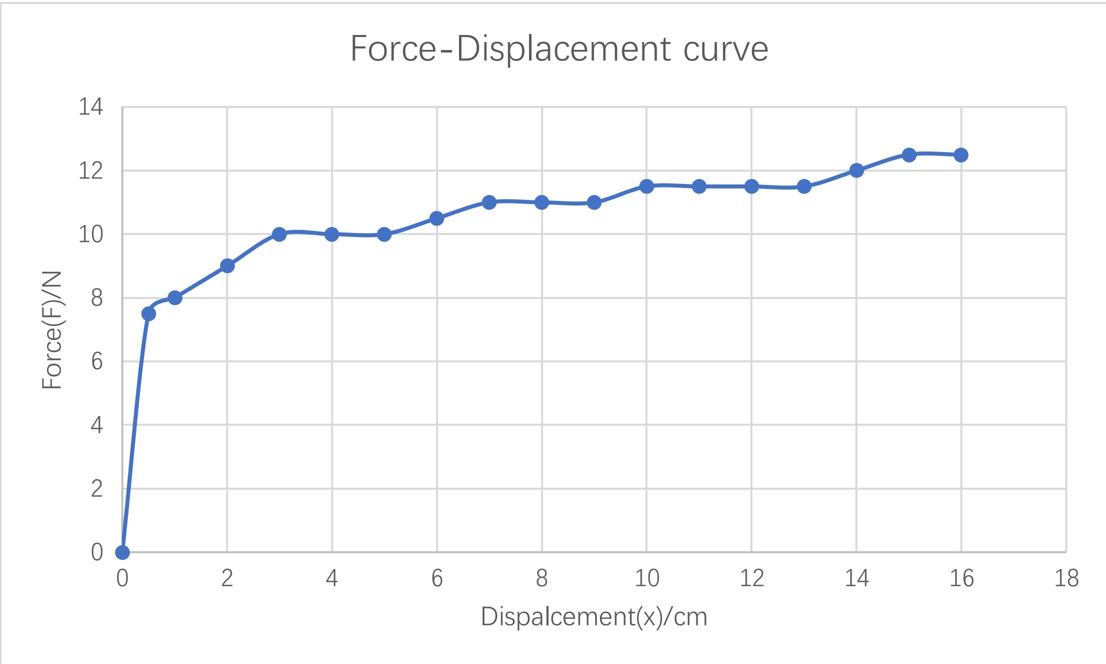


Fig 4.2 Force-Displacement curve for 0.8mm thick carbon bars

We get：

$$E \;=\; 1.7J$$

So we can find the robot bounce height as (neglecting air resistance and other factors)：

$$h = \frac{E}{mg} = \frac{1.7J}{0.093kg \times 9.8m/s^2} = 1.87m$$

This result is not satisfactory. So we repeated the above experiment again using a 1.2mm thick carbon bars and got a new set of results in Fig 4.3：

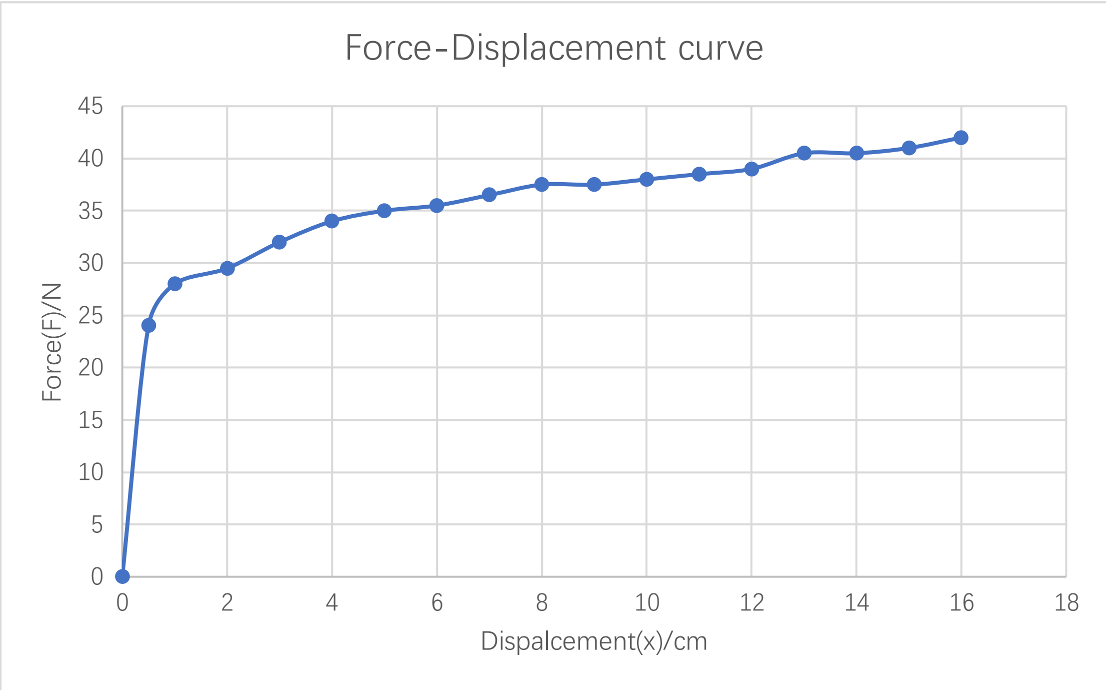


Fig 4.3 Force-Displacement curve for 1.2mm thick carbon plates

We get:

$$E = 5.32J$$

So, the jumping height becomes:

$$h = \frac{5.32J}{0.093kg \times 9.8m/s\text{^}2} = 5.84m$$

This result is satisfactory. The robot can theoretically jump to a high enough height to meet our design expectations

5. Discussion

5.1 Design Critique

5.1.1 Advantages

The biggest advantage of our design is that the mechanism jumps high enough.

During the century test calculations, it can jump close to 6 meters without considering air resistance. The comparison of our design to other designs is shown in Fig 5.1.

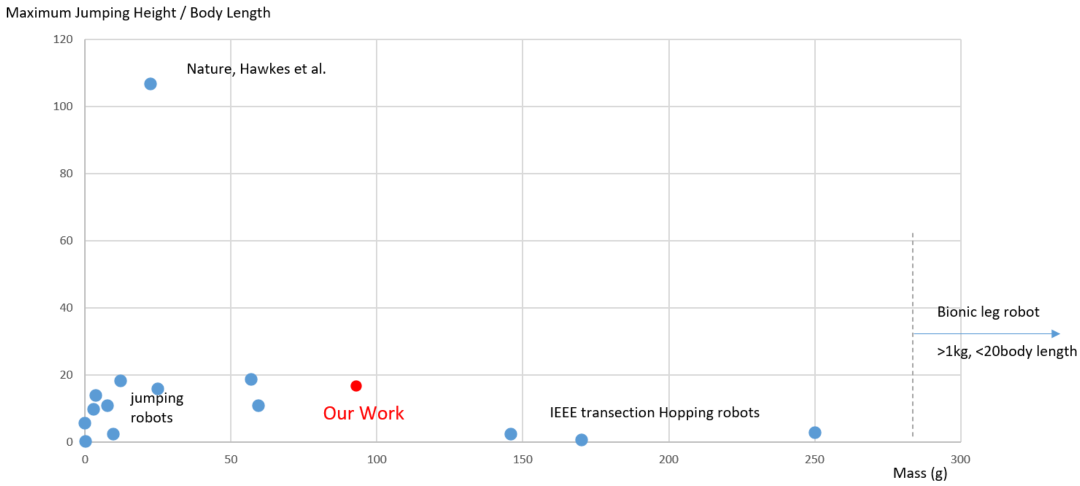


Fig 5.1 Maximum Jumping Height/Body Length for small mass robot

What's more, the jumping direction can be adjusted. In the design process, we fully consider that the robot will not jump straight up when jumping, but may have to lean in all directions to jump. Therefore, there are three angle adjustment devices in our design, which can work together to meet the needs of the robot to jump in any direction.

During the design process, we have also taken more into account the aspect of safety performance, so although the quality of the design mechanism has been higher and weight reduction is more difficult, the safety can be guaranteed.

5.1.2 Weakness

Our design does not allow the robot to jump automatically and continuously, and we need to do manual adjustments after each jump. Our initial idea to solve this problem was to use a servo attached to the release arm. However, the problem with this method is that the servo is heavy, and the lightest servo we found online has a weight of 8g, which will greatly increase the burden on the robot. Moreover, if the servo is attached, the release mechanism will need to be redesigned.

Besides, because of safety considerations and the existence of angle adjustment devices, even after the weight reduction, our design still weighs 100g, which causes the height of the jump is not as high as expected. Therefore, we prefer to further reduce the weight of the design in the physical testing process

5.2 Recommendations

In the future developments, there are several recommendations.

First, we need to further simplify the structural design of the angle adjustment part, for example, we can directly use the carbon plate to connect the screw motor to reduce the weight.

Secondly, we can attach more functions to the design, for example, continuous jumping. We can also attach other functions such as IMU sensing and automatic adjustment, making it a comprehensive product.

Last but not least, some more detailed designs should be improved to further simplify the assembling process. Actually, there are still many difficulties during the assembling process. Also, some modifications can be made for better performance.

6. Conclusion

In conclusion, the jumping robot we designed can jump to a considerable height, which meets the need of the project challenge competition. It can also adjust its position with the self-righting unit and jump in a given direction, which means high controllability. However, there are still some weaknesses for this design. For example, it cannot jump continuously. There are also some redundant weights which can affect the performance of the robot. In the future development, we will attach more functions to it and further simplify the structure to perfect its performance.

7. Acknowledgements

We would like to express our sincerest gratitude to Prof. Peter Shull for his dedicated tutoring in class and guidance of our project.

We feel grateful to our TA. Li Dongxuan and Wang Hong for their helping us to learn this course better and aiding us to make our project better.

We are thankful to Teacher Qian Changming and Master Yan Wei for giving us valuable advice on this project.

We’d like to thank our classmates and friends for giving us comments and encouraging us.

We’d like to appreciate all of our group member’s work. We all enjoy this project and have a happy time in this team.

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9. Appendix

Appendix A The division of labor among team members

Hu Qingsong: Group leader; Part 3;

Gu Enlin: Part 2; Calculation in part 3.2.2, 3.2.3; Participate in part 4,5;

Jiang Zhiheng: Chief editor (revise the whole report); Part 3.4; Part 6; Summary, content, etc.;

Fang Shengjian: Part 4,5; Making PPT; Appendix D (schematic);

Li Muhan: Part I; Appendix B (coding); Appendix C (part list);

Appendix B The Jumping Robot Control Code

蓝牙串口调试:

```
#include <SoftwareSerial.h>
// Pin10 接 HC05 的 TXD
// Pin11 接 HC05 的 RXD
SoftwareSerial BT(10, 11);
char val;

void setup() {
   Serial.begin(38400);
   Serial.println("bluetooth is ready!");
   BT.begin(38400);//设置波特率
}

void loop() {
   if (Serial.available()) {
      val = Serial.read();
      BT.print(val);
   }

   if (BT.available()) {
      val = BT.read();
      Serial.print(val);
   }
}
```

电机驱动模块:

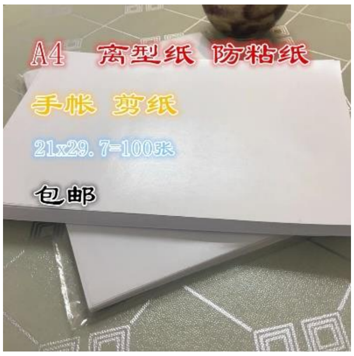
```
enA=9
in1=6
in2=7
void setup() {
pinMode(enA, OUTPUT);
pinMode(in1, OUTPUT);
pinMode(in2, OUTPUT);
// Set initial rotation condition (stop)
digitalWrite(in1, HIGH);
digitalWrite(in2, HIGH);
int flag = true;
}
void loop() {
delay(2000);
if (falg==true) //judge whether the loop has to be operated
{
int pwm=255; // set max PWM signal
```

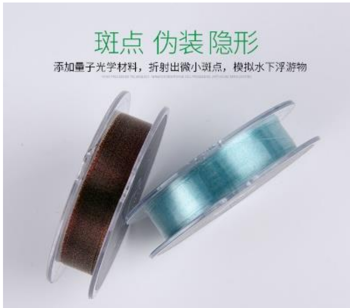
```
analogWrite(enA, pwm); // Send PWM signal to L298N Enable pin
digitalWrite(in1, HIGH);
digitalWrite(in2, LOW);//start the motor
delay(20000);//operate the motor for 20seconds
digitalWrite(in1, HIGH);
digitalWrite(in2, HIGH);//stop the motor
flag=false;//stop operating in the following loops
}
delay(2000);
if (Serial.available() > 0) {
    // read the incoming byte:
    int incomingByte = Serial.read();
if (incomingByte==1)
flag=true;//if we give an input of 1 from our device, start jumping loop again
}
```

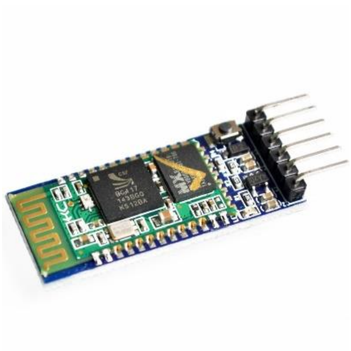
Appendix C. Parts list

Parts	Number&Price	Bought	Use/advantage
Arduino nano SCM 单片机  Dubond thread 杜邦线 	1*SCM+3*thread ￥49.97	Taobao——zave 旗舰店【淘宝】https://m.tb.cn/h.UjpzOrt?tk=0RhJd3pzuo1 CZ0001 「arduino nano uno 开发板套件 r3 主板改进版 ATmega328P 单片机模块」【淘宝】https://m.tb.cn/h.U8qVSgz?tk=PkjPd3pzdr9 CZ3457 「杜邦线 母对母 公对公 公对母 10/15/20/30/40cm 连接线 40P 彩色排线」	● Motor control ● Small volume and weight
DC motor 直流电机 GA12-N20 30rpm6V 	2* ￥23.00	Taobao——创杰电机【淘宝】https://m.tb.cn/h.URwo8aD?tk=EnNwd3KZ06q CZ0001 「GA12-N20 减速电机微型直流齿轮智能锁小马达 3V6V12V 智能小车低速」	● Bending the carbon plate

DC motor 直流电机 GA12-N20 60rpm6V  Lead screw motor 丝杆电机 GA-N20 50rpm6V  	1*DC+1*LS ￥40.50	Taobao——新华通电子厂家直销 【淘宝】https://m.tb.cn/h.URwo8aD?tk=EnNwd3KZ06q CZ0001 「GA12-N20 减速电机微型直流齿轮智能锁小马达 3V6V12V 智能小车低速」 【淘宝】https://m.tb.cn/h.URYgCYI?tk=VesJd3KaAvK CZ0001 「GA12-N20 精密减速马达智能小车 3V6V12V 微型直流齿轮减速低速电机」	• Bending the carbon plate • Return ability
lithium battery 锂电池 3.7V100mA  	4* ￥42.00	Taobao——顺心通电子有限公司 【淘宝】https://m.tb.cn/h.U8q6pNu?tk=dJ3Pd3KYLEv CZ0001 「可充电 3.7v 可充电锂电池 5V 胎压监测行车记录仪手表耳机通用电芯」	• Power supply • Small volume and weight
industrial tape 工业胶带 	1* ￥19.00	Taobao——亚多利办公专营店 【淘宝】https://m.tb.cn/h.URYRorJ?tk=BQH6d3K1OY6 CZ0001 「银色胶带高粘度超强银灰色强力胶带工业用高粘度牛皮胶带胶布贴强力高粘度布胶带高粘耐磨布基地毯大力胶单面」	• Fixing the carbon plate • High strength and smaller stretcher strain

release paper 离型纸  	1* ￥15.04	Taobao——泰典旗舰店 【淘宝】 https://m.tb.cn/h.URY87F7?tk=8tYwd3KXNxJ CZ3457 「A4 防粘纸 A5 离型隔离硅油纸 A6 手粘胶带防粘纸 B6 离型隔离硅油纸和纸胶带垫纸热转印双面胶衣服隔离纸本防潮定制」	
rubber band 橡皮筋 10mm*1.4mm*32mm 10mm*1.4mm*38mm 10mm*1.4mm*50mm  	1* ￥18.90	Taobao——丝芳花园 【淘宝】 https://m.tb.cn/h.UjKWXly?tk=Y2aTd3Kdpcr CZ0001 「耐用 5MM 宽黄色橡皮筋包邮 10MM 大号橡皮圈橡胶圈牛筋乳胶圈粗皮筋」	● Smoothening the curve of elasticity
Stainless steel optical shaft 不锈钢光轴 1.5mm 2.5mm 4.0mm  	3* ￥19.26	Taobao——绍思五金专营店 【淘宝】 https://m.tb.cn/h.URwuNtZ?tk=VtHvd3KWHV2 CZ3457 「304 不锈钢光轴轴体直线光杆导轨轴杆 1 2 35 4 6 7 8 9 30 40mm 轴」	

micro bearing 微型轴承 开式 4*7*2  	10* ￥12.00	Taobao——yxvsy 旗舰店 【淘宝】https://m.tb.cn/h.U8qQVMS?tk=FL1dd3KVgV9 CZ3457 「迷你微型轴承小内径 1 1.5 2 2.5 3 4 5 6 7 8 9 mm 高速模型 DIY 精密」	
fishing thread 鱼线  	1* /	Get it by ourselves	● Bending the carbon plate ● High strength
motor driving module 电机驱动模块 	1* /	Borrowed from Student Innovation Center	● Motor control
hex nut 六角螺母 M3  	15* /	Borrowed from Student Innovation Center	

Hc-05 bluetooth module 蓝牙模块 	1* /	Borrowed from Student Innovation Center	● Remote control
3Dprinting parts 	196yuan (each edition) (2yuan/gram)	Bought from taobao	● Structure parts ● More details in the report part I
Flexible Rods 	About 130yuan (each edition)	Bought from taobao	● Major energy storage parts

Appendix D. Schematics

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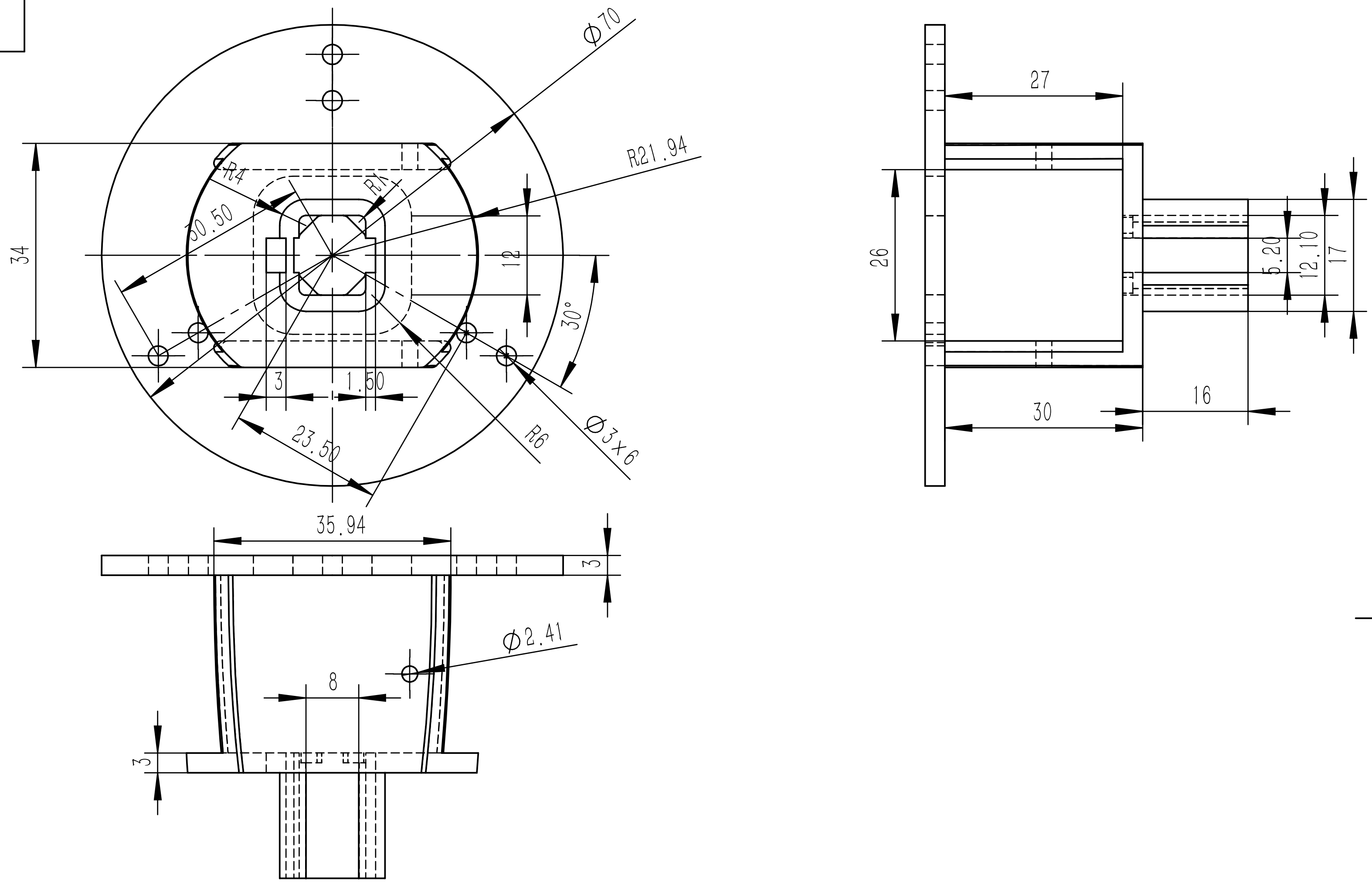

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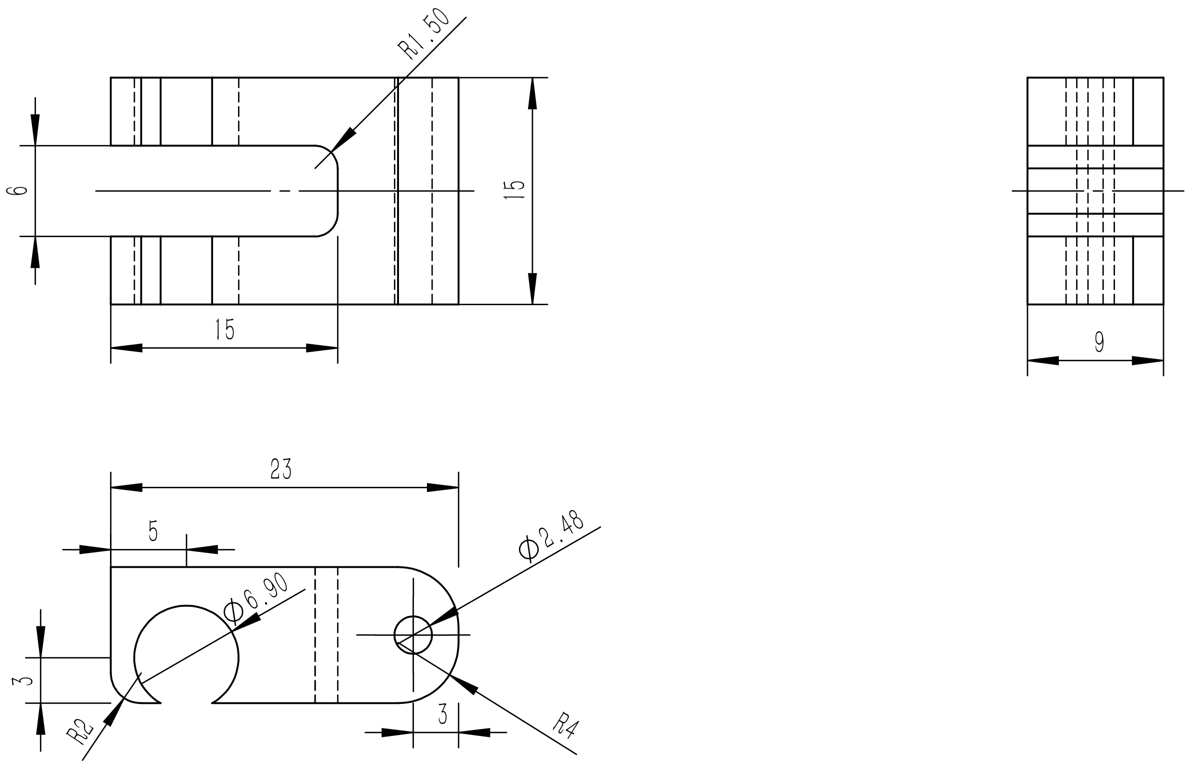

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主管设计			审核					
			批准			共1 张 第1张	版本	

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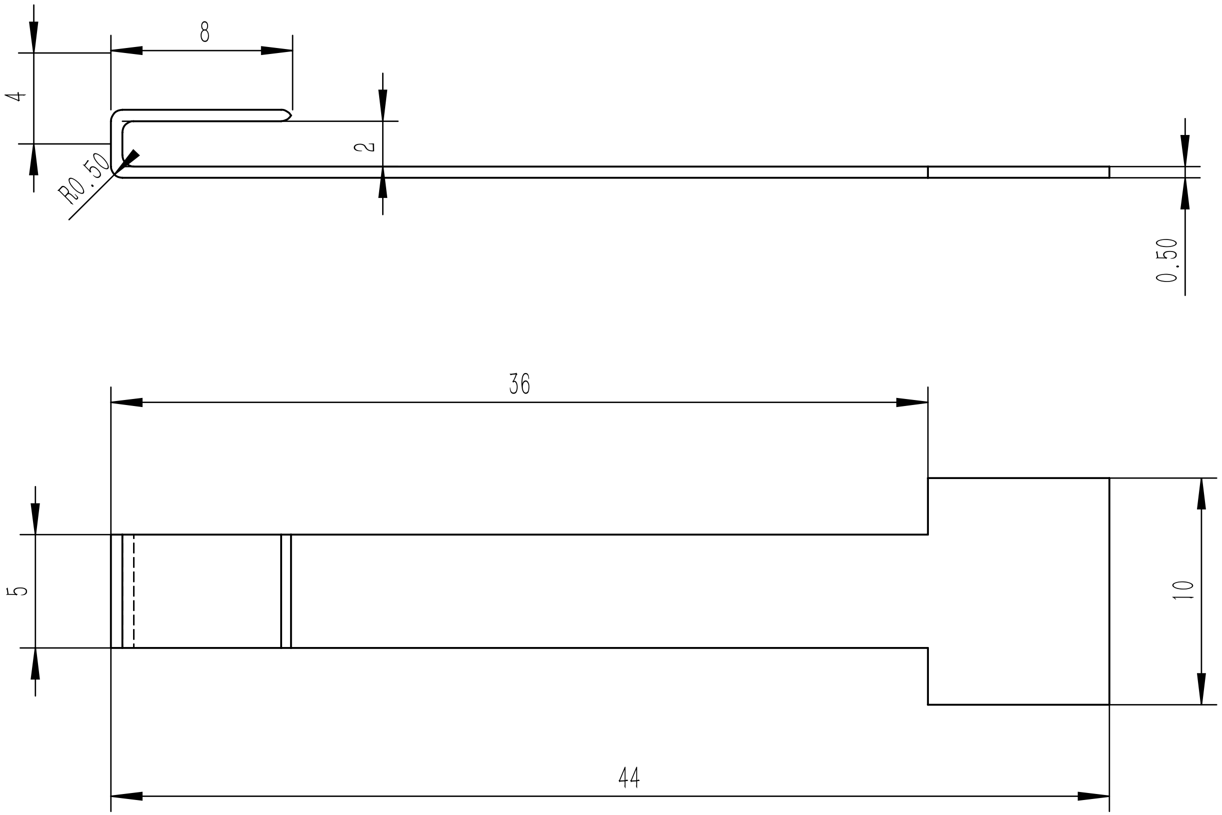

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			批准			

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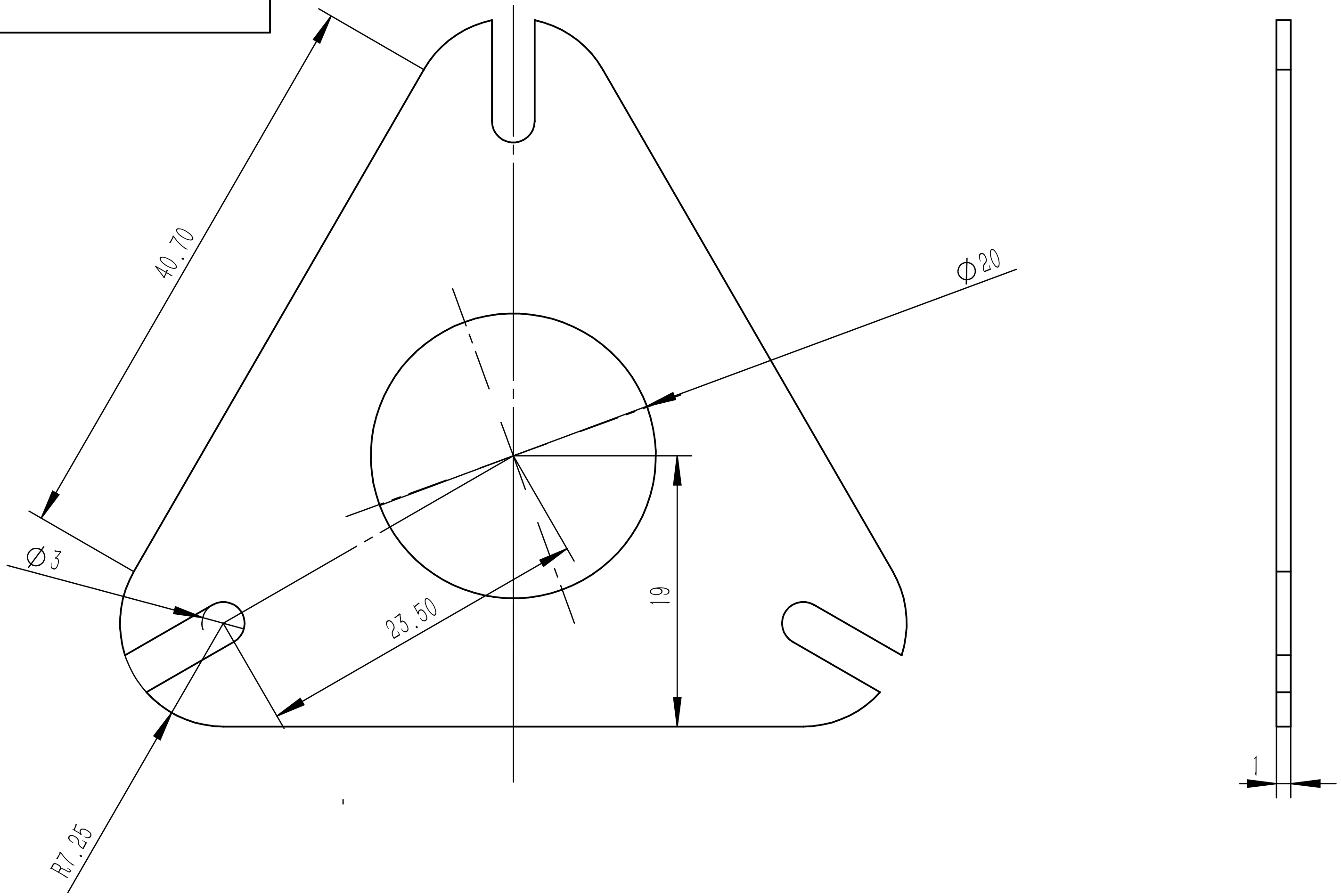

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主管设计			审核		
			批准		

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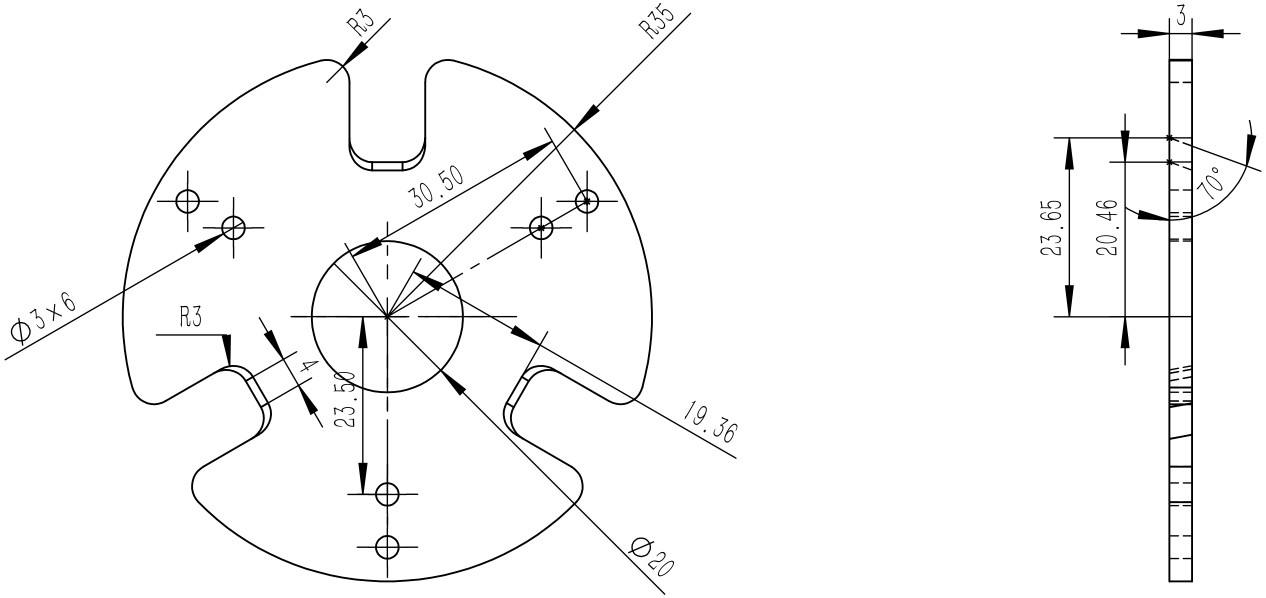

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设计			标准化			0.009 / 1:1	
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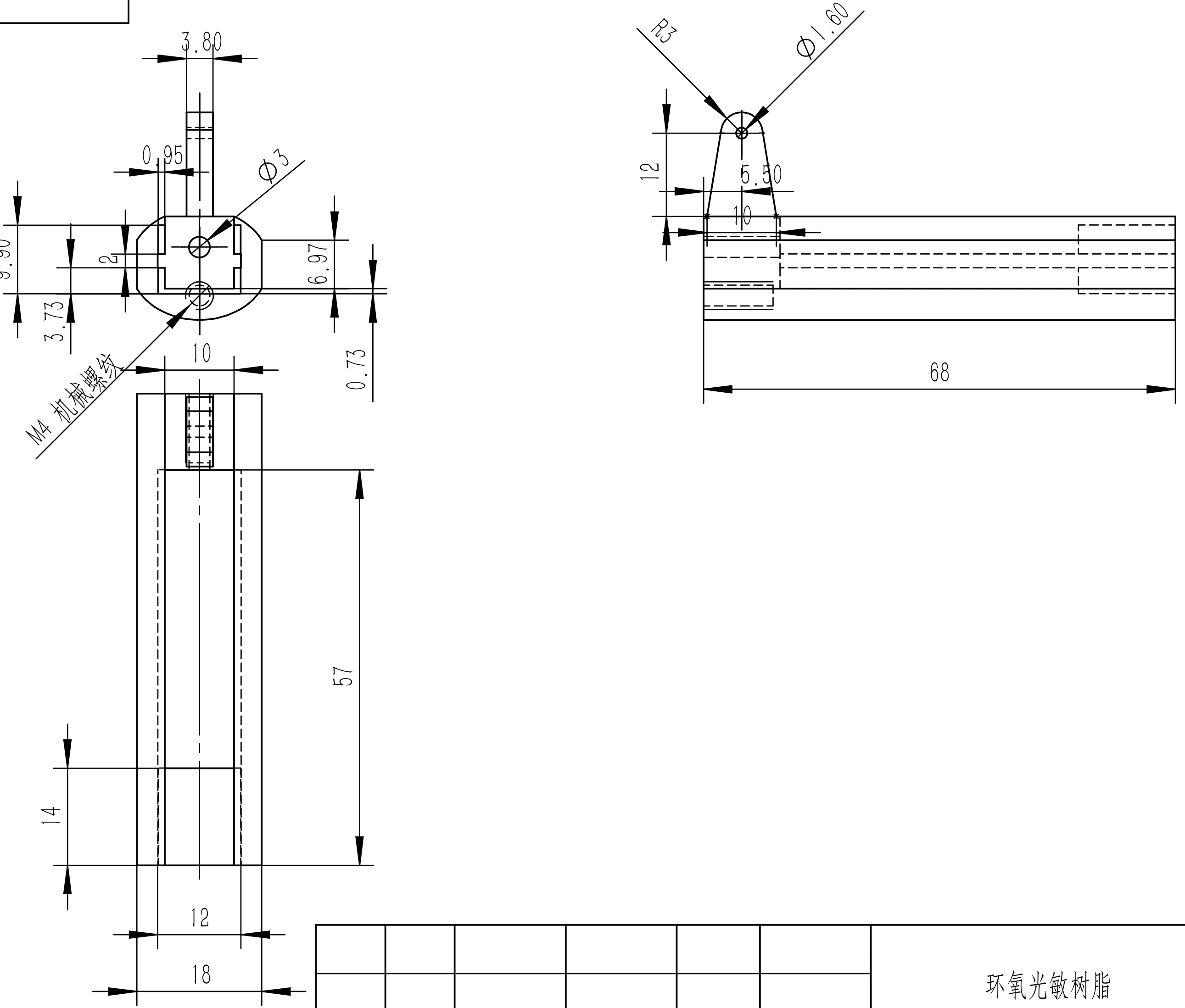

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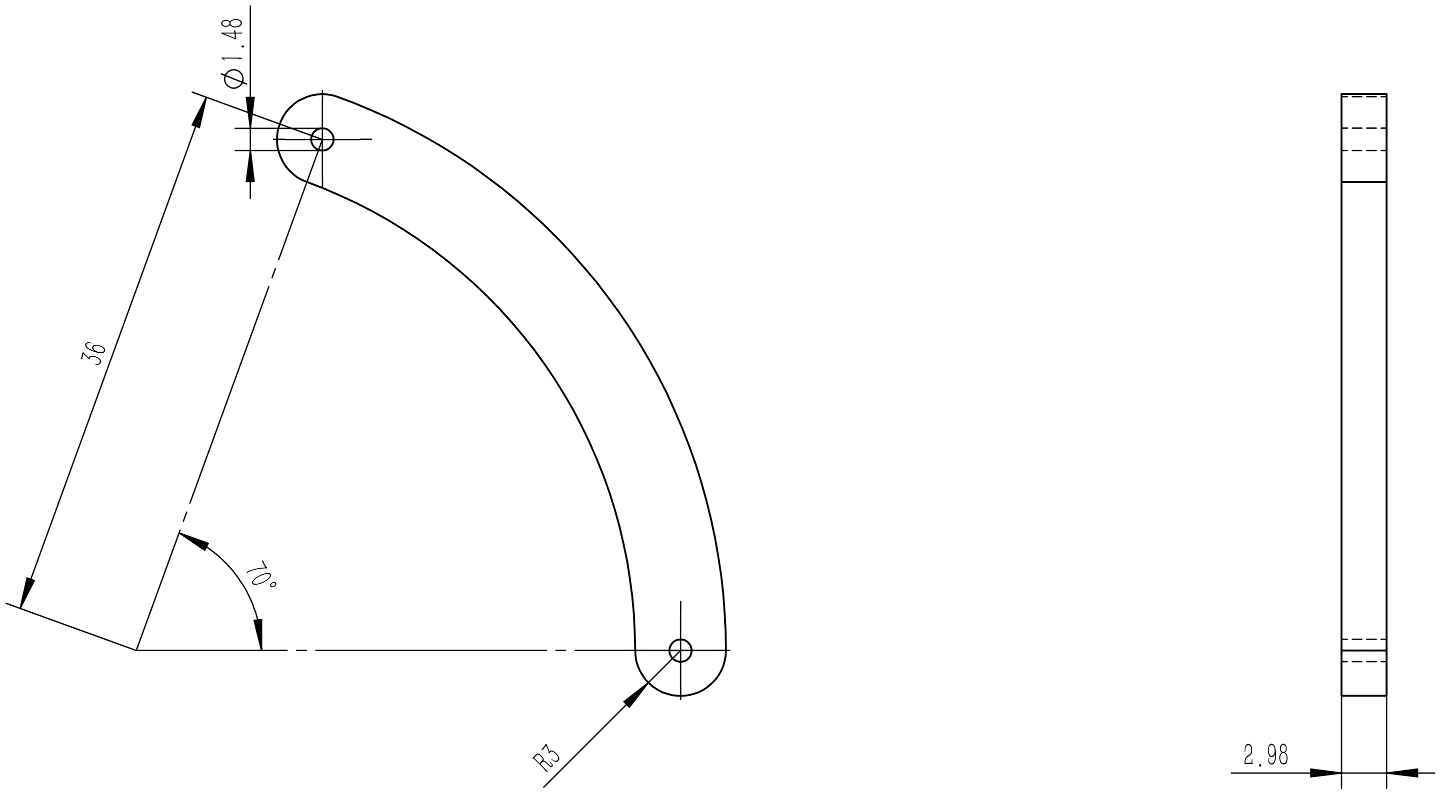
共1 张 第1张 版本 替代

7

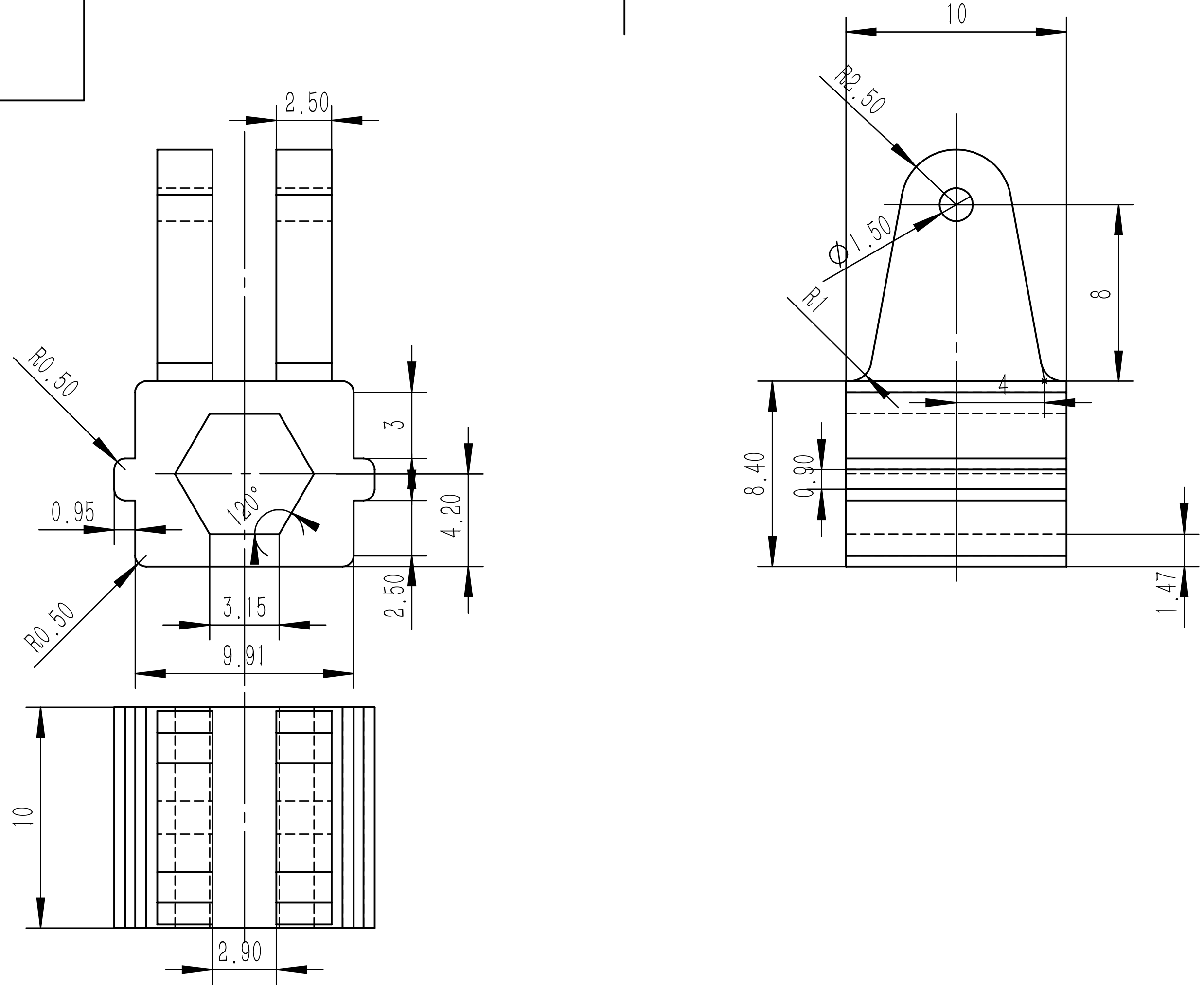


零件代号	
借(通)用件登记	
旧底图总号	
底 图 总 号	
签 字	
日 期	

						环氧光敏树脂			
标记	处数	分区	更改文件号	签名	年 月 日	阶 段 标 记	质量	比例	coupler
设计			标准化				0.001	2:1	
校核			工艺						7
主管设计			审核						
			批准			共1 张 第1张	版本		替代

1	2	3	4	5	6

8

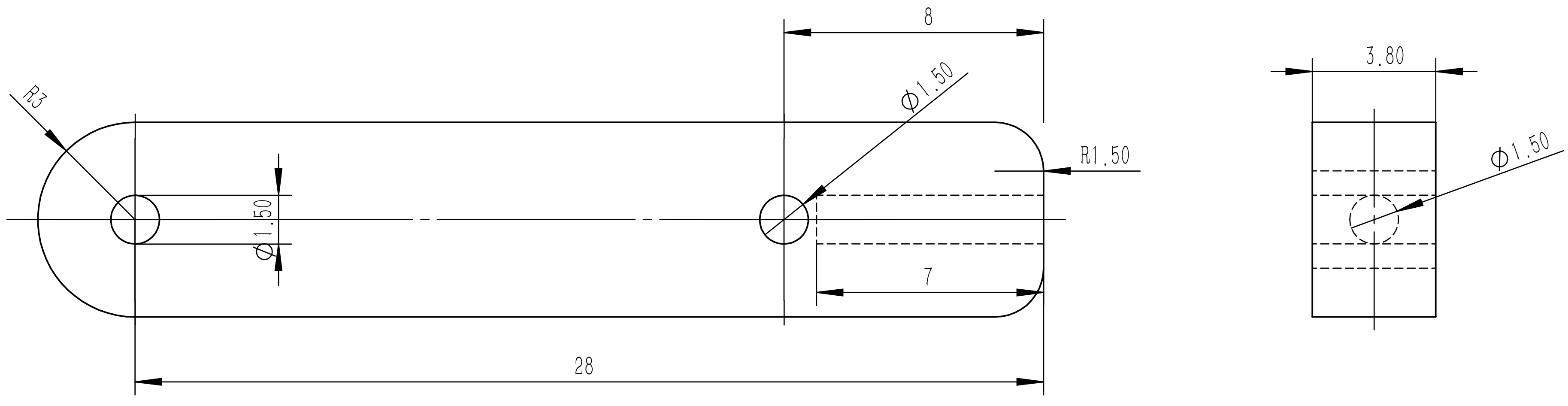


零件代号	
借(通)用件登记	
旧底图总号	
底 图 总 号	
签 字	
日 期	

						环氧光敏树脂	
标记	处数	分区	更改文件号	签名	年 月 日	阶 段 标 记 / 质量 / 比例	slider
设计			标准化			0.001 / 3:1	
校核			工艺				8
主管设计			审核				
			批准			共1 张 第1张 版本	替代

1	2	3	4	5	6

6



零件代号

借(通)用件登记

旧底图总号

底 图 总 号

签 字

日 期

标记	处数	分区	更改文件号	签名	年 月 日
设计			标准化		
校核			工艺		
主管设计			审核		
			批准		

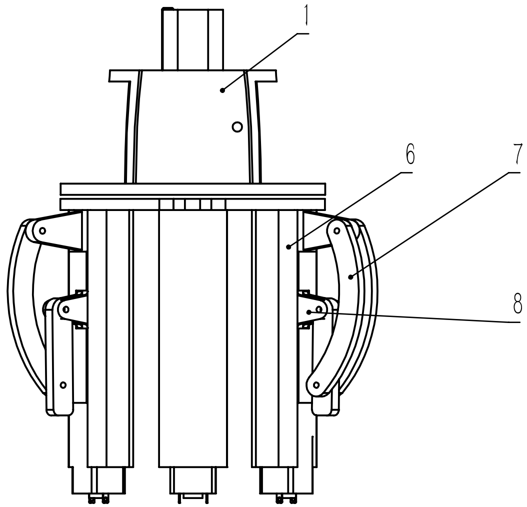
环氧光敏树脂

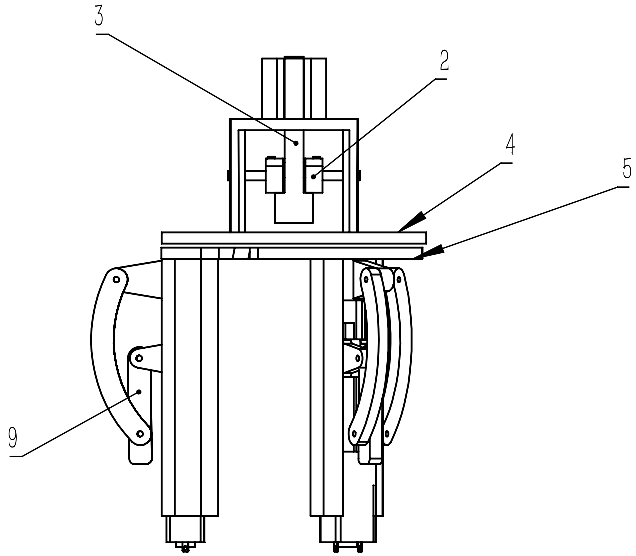
阶 段 标 记	质量	比例
	0.001	5:1

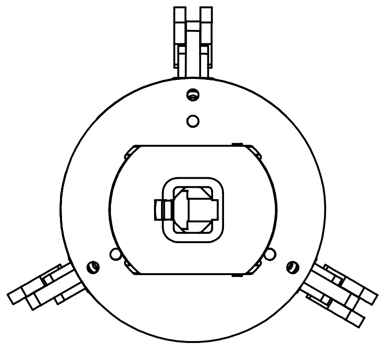
共1 张 第1张 版本 替代

Rocker

9







9	rocker	3	环氧光敏树脂	
8	slider	3	环氧光敏树脂	
7	coupler	6	环氧光敏树脂	
6	slide—way	3	环氧光敏树脂	
5	upper—connector	1	环氧光敏树脂	
4	bar—upper—connector	1	环氧光敏树脂	
3	latch	1	环氧光敏树脂	
2	Release—arm	2	环氧光敏树脂	
1	Inner—cover	1	环氧光敏树脂	
序号	名称	数量	材料	备注

零件代号

借(通)用件登记

旧底图总号

底 图 总 号

签 字

日 期

标记	处数	分区	更改文件号	签名	年 月 日
设计		标准化			
校核		工艺			
主管设计		审核			
		批准			

阶 段 标 记	质量	比例
	0.088	1:2

Jumping Robot Assembly

1

共1 张 第1张 版本

替代