重庆大学

机械原理课程报告

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项目内容：玻璃升降器

学生姓名：易弘睿 冯灏霆 韩翔宇 庄研 杨睿

学院专业班级：UC 联合学院 2018 级机械 01 班

学　　号：20186103 20186100 20186102
20186105 20186115

任课教师：刘达斌

重庆大学机械与运载工程学院

CQU-UC Joint Co-op Institute (JCI)
Student Project Report
Final project of theory of machines and mechanisms
Window regulator

Institution CQU-UC Joint Co-op Institute (JCI)

Grade 2018 **Major** Mechanical Engineering **Class** 01

Student Name Yi, Hongrui **Student Number** 20186103

Student Name Feng, Haoting **Student Number** 20186100

Student Name Han, Xiangyu **Student Number** 20186102

Student Name Zhuang, Yan **Student Number** 20186105

Student Name Yang, Rui **Student Number** 20186115

Academic Year 2021 Summer

Course Code: ME31803 **Instructor** Liu, Dabin

CQU-UC Joint Co-op Institute

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ABSTRACT

This report studies the mechanism diagram, degree of freedom, assembly, kinematics and dynamics analysis of the glass lifter. We use two methods to analyze the kinematics problem, and finally find that the second method can get a more accurate solution. Through the analysis of these problems, we have a better understanding of the glass lifter and the application of the mechanical principal course.

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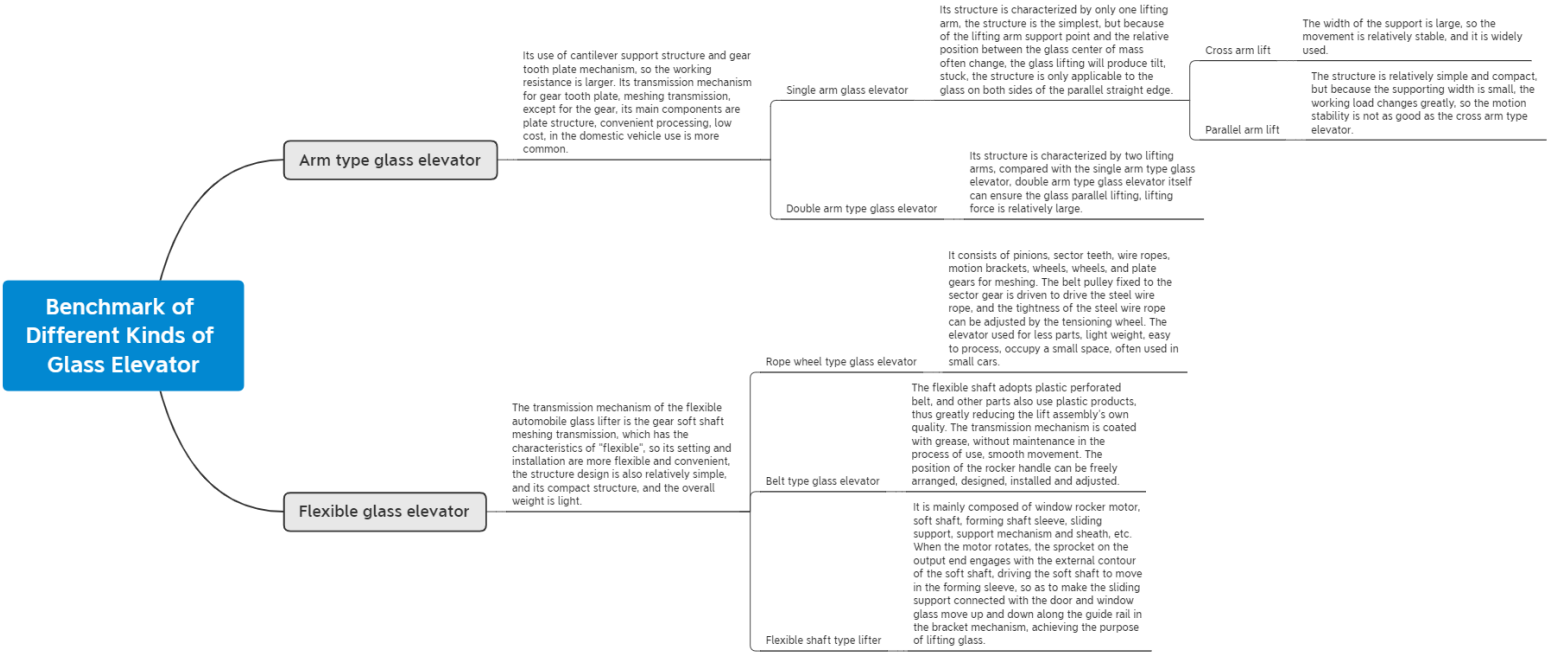
1. Benchmark of Different Kinds of Glass Elevator

1.1 The flow chart of benchmark



1.2 Benchmark of Different Brands of arm type glass elevator

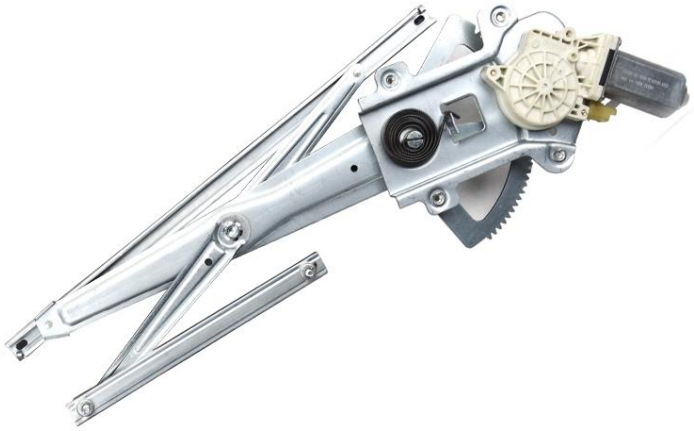
1.2.1 Great Wall Jiayu/ Tengyi V80(125RMB)

Brand: Xiudehao Auto Service Department

Material: cold rolled steel plate + pure copper motor + booster spring

Product advantages and features: The lifter bracket is made of oil-surface galvanized sheet, which has better physical properties such as hardness, and chemical properties such as rust, corrosion, and oxidation

resistance to better protect the life of the lifter. The lifter adopts power assist and booster spring, which can better ensure the stability of the lifter and prevent the motor from overloading.

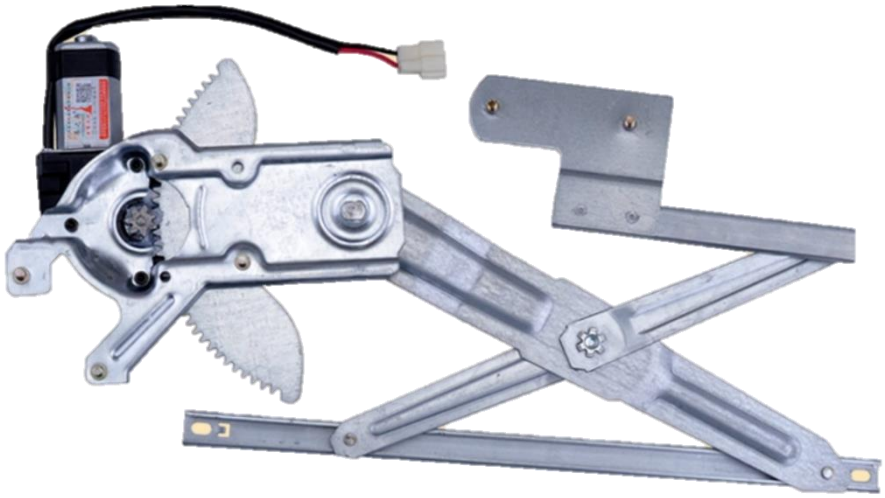


1.2.2 Yellow Sea/Challenger/ Aolong(171RMB)

Brand: Chezhizhou

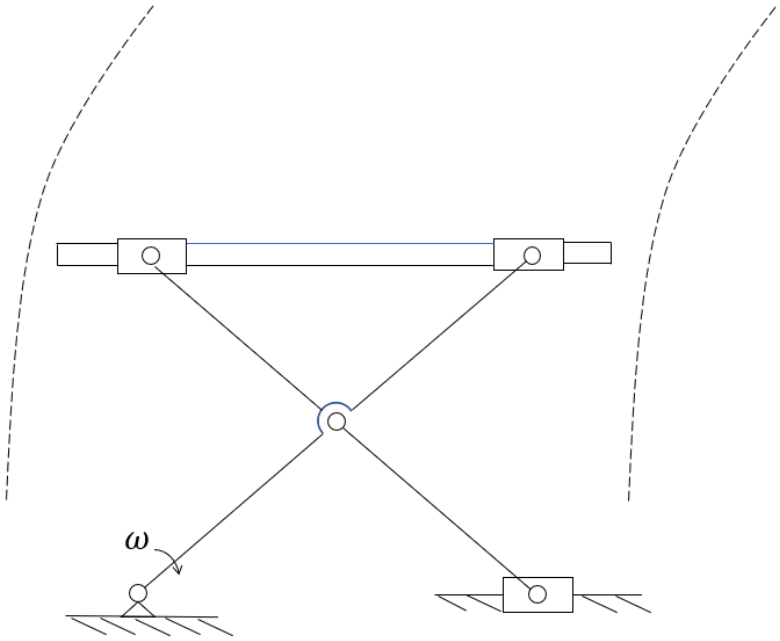
Material: The motor is made of pure copper

Product advantages and features: The motor speed of the lifter is stable and powerful, and the noise is low. It has waterproof protection, overload protection and other functions, as well as power-off protection in the case of short circuit, overheating, etc., with excellent safety



2. Calculation of degree of freedom

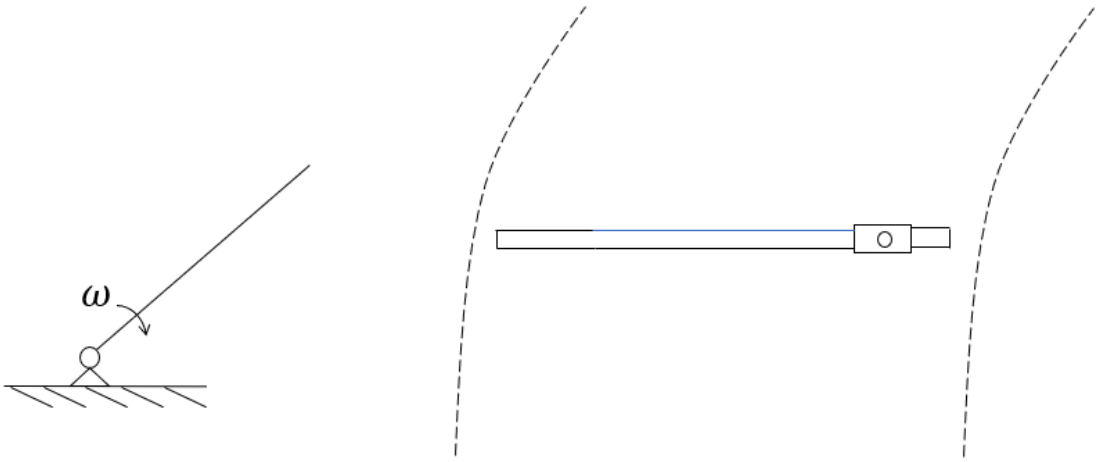
2.1 Diagram



2.2 Calculation of Degree of freedom

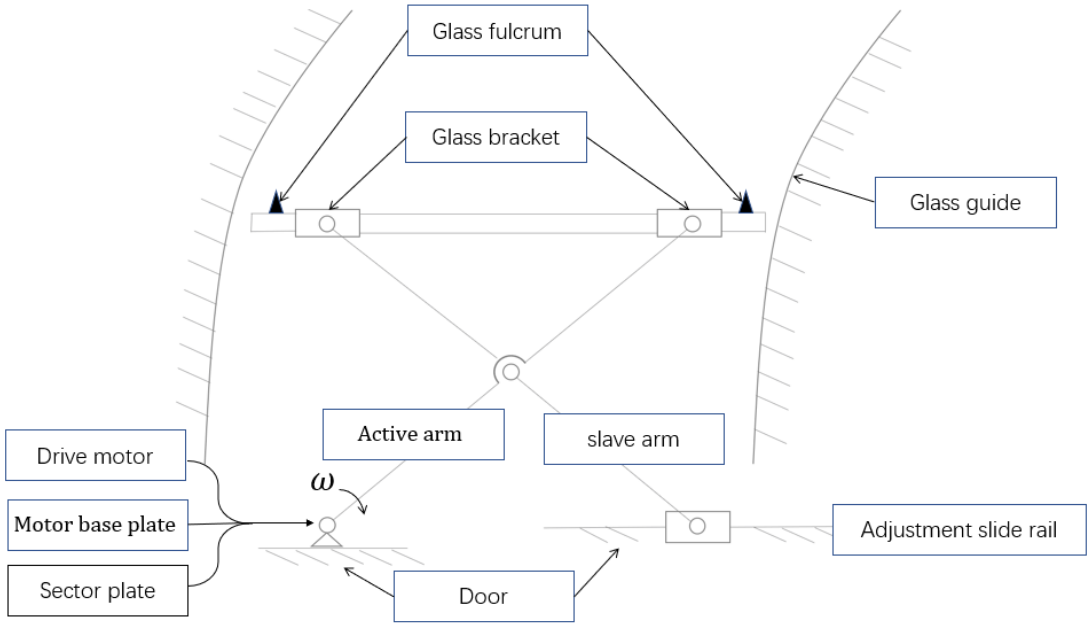
$$D.O.F. = 3 * 3 - 2 * 4 = 1$$

3. Division of Assur-Group



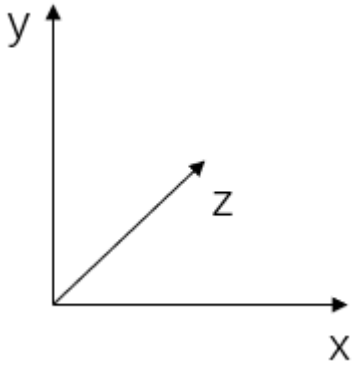
If we select the slave arm and two related sliders as the Virtual constraint, which can be estimated, then, the mechanism can be divided into three elements. Because the guide rail of the upper slider is viewed as one slider along the window glass guide, the rail is considered moving along the guide without rotation but only slide. Furthermore, the mechanism can be divided into one prime mover and one PPR IIAssur-group. It is aIIlevel mechanism.

4. How to install the glass



For the installment of the glass, the installment needs to ensure the center of gravity of the glass coincide with the center of gravity of the x-bar window regulator as much as possible, which can reduce the moment of force and make the structure more stable. At the same time, when installing, pay attention to that the mounting bracket and the slide block are not closely connected, and there is a gap so that the sliding block can be relative to the sliding guide rail along X, Y, Z direction. This also explains how to generate three degrees of freedom from one D.O.F. of the prime mover, and make the window slide up and down along the door curve and closely cooperate with each other, so as to avoid the jamming between the glass and the glass guide rail, damaging the glass and generating noise.

5. 3-DOF Analysis



The doors and windows are curved surfaces, so in addition to the degrees of freedom in the X and Y directions, the degrees of freedom in the Z direction are also needed to make the glass move along the curved surface.

5.1 x-direction:

Due to the vertical upward movement of the glass bracket.

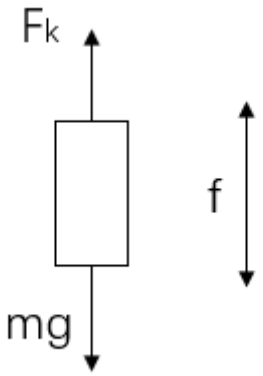
5.2 y-direction：

Due to the restriction of the glass guide in Y direction, the slider on the glass bracket moves along the Y direction.

5.3z-direction:

Due to the restriction of glass guide rail in Z direction and the glass bracket can shake along z direction, there is Z-direction movement of glass.

6. Function of butterfly spring



It plays a supporting role in the process of glass lifting.

1. Provides upward elasticity during glass rising to reduce power consumption

2. When the glass is static, it can provide elastic force to prevent it from falling

3. In the process of glass falling, the elastic force is provided to prevent the glass from falling too fast and make the glass fall more smoothly

7. Kinematics and dynamics analysis (two methods)

In the first method, we use the form of differential equation to calculate the angular velocity. However, because the curve fitting error is large, and this method is not easy to obtain the pressure angle, we give a second calculation method based on geometry. The second method can accurately calculate the angular velocity expression, and the error is small, so we also use the second method in the calculation of pressure angle.

7.1 Method 1: Differential equation

7.1.1 Establishment of kinematics equation

By assuming that the speed of window rising is constant, the expression of the angular velocity of the motor is obtained. Since the ascending and descending processes of the window glass are symmetrical, we only study the ascending process of the glass.

7.1.2 Assumptions

1. The rising speed of glass remains constant.

2. The rising process of glass is symmetrical about the fulcrum of active arm.

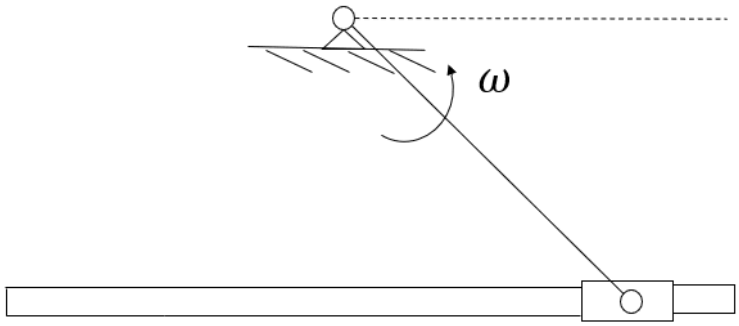
3. Only one degree of freedom motion is considered

7.1.3 Data measurement:

1. Length of driving arm is 34cm by measurement
2. Window height is 36.5cm from Internet
3. Window moving up time is 4.2s from Internet

7.1.4 Process

1. Process 1



According to the velocity analysis, we get the following equation, where V is the constant and equal to 0.0869 m/s.

$$\omega L\cos\theta(t)=V$$

We can get the angle from the following equation.

$$\theta(t)=\theta_1-\int_0^t\omega(t)dt$$

Put it into the above equation, we can get

$$\theta_1-\int_0^t\omega(t)dt=\arccos(\frac{V}{L\omega(t)})$$

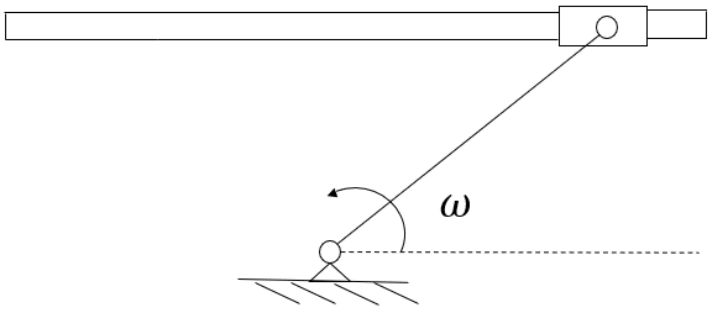
Take derivation for two sides, we get

$$-\omega(t)=\frac{V}{L}\frac{\omega'(t)}{\omega^2(t)}\frac{1}{\sqrt{1-\frac{V^2}{L^2\omega^2}}}$$

Finally, we can get

$$\omega'=-\frac{L}{V}\omega^3(t)\sqrt{1-\frac{V^2}{L^2\omega^2(t)}}$$

2. Process 2



According to the velocity analysis, we get the following equation, where V is the constant and equal to 0.0869 m/s.

$$\omega L\cos\theta(t)=V$$

We can get the angle from the following equation.

$$\theta(t)=\int_0^t\omega(t)dt$$

Put it into the above equation, we can get

$$\int_0^t\omega(t)dt=\arccos(\frac{V}{L\omega(t)})$$

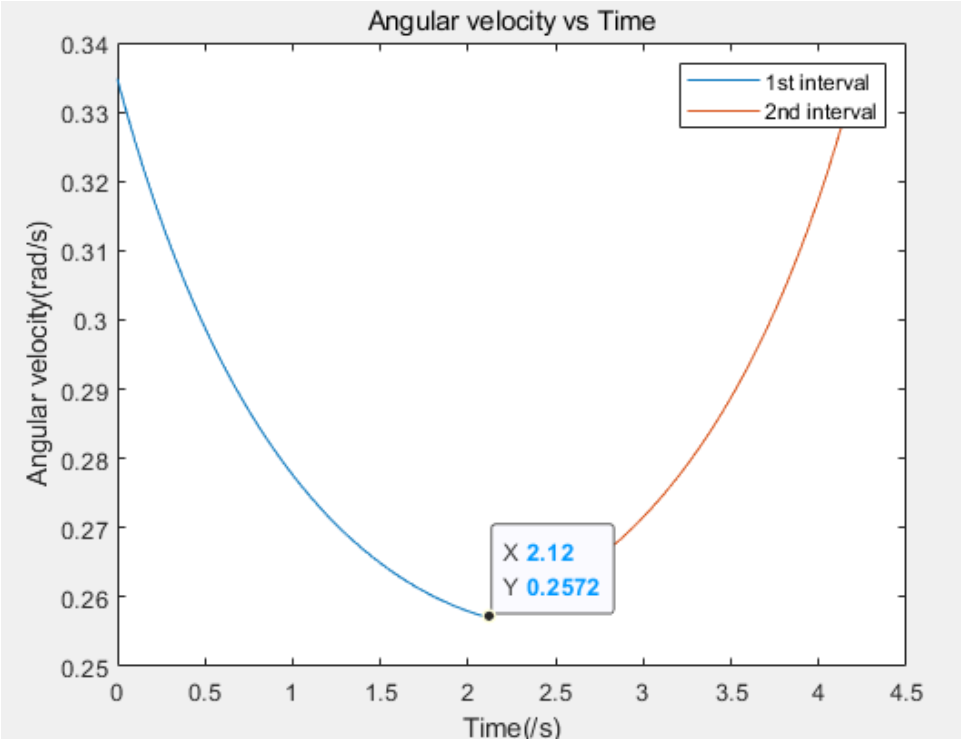
Take derivation for two sides, we get

$$\omega(t)=\frac{V}{L}\frac{\omega'(t)}{\omega^2(t)}\frac{1}{\sqrt{1-\frac{V^2}{L^2\omega^2}}}$$

Finally, we can get

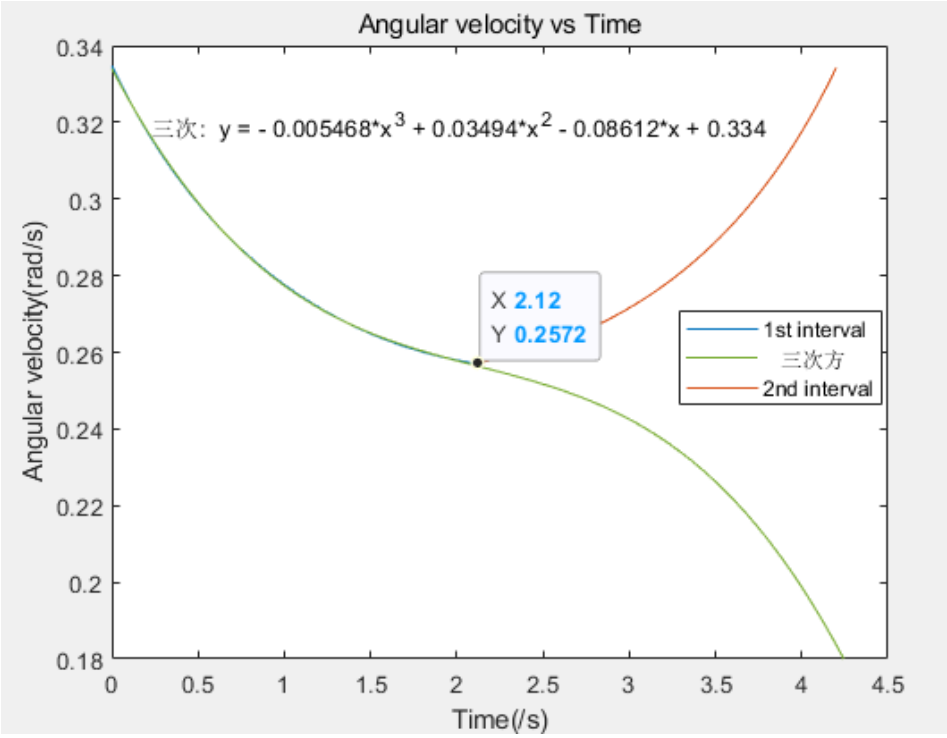
$$\omega' = \frac{L}{V}\omega^3(t)\sqrt{1-\frac{V^2}{L^2\omega^2(t)}}$$

We use Classical Fourth-Order Runge-Kutta Method to solve these two differential equations, we get the graph of w(t).

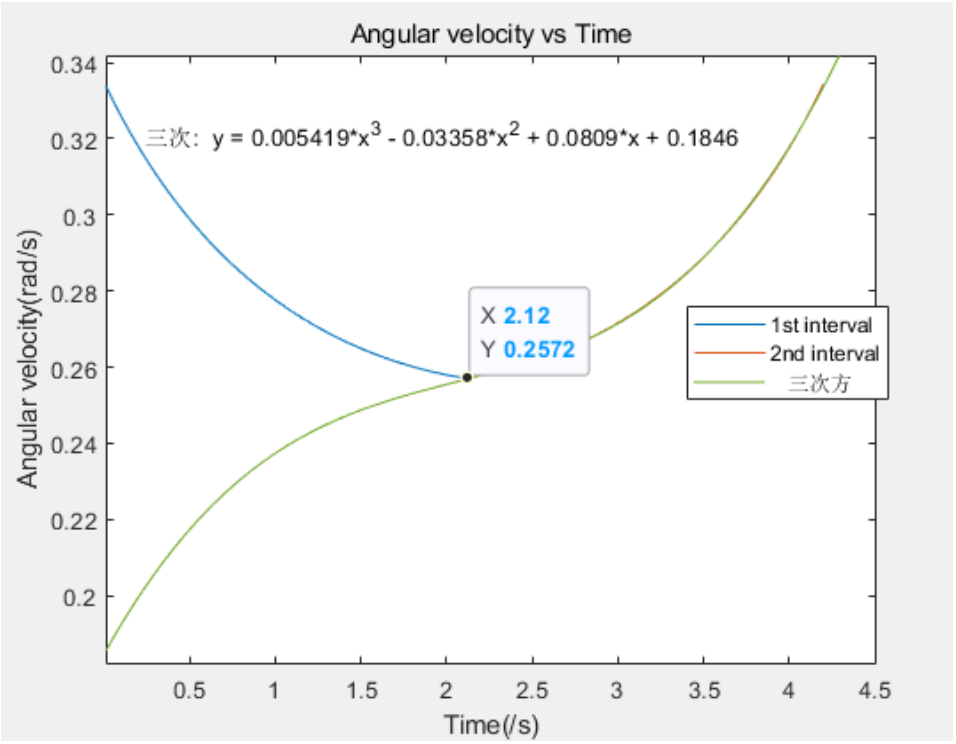


7.1.5 Fitting of angular velocity formula of active arm

Then we use the cubic polynomial fitting according to the data obtained from Fourth-Order Runge-Kutta Method, then we get the equation.



$$\omega = -0.005468t^3 + 0.03494t^2 - 0.08612t + 0.334 \quad (0s < t \le 2.1s)$$



$$\omega = -0.005419t^3 - 0.03358t^2 + 0.0809t + 0.1846 \quad (2.1s < t \le 4.2s)$$

7.1.6 Formula of motor angular velocity

The calculated angular velocity formula is about the active arm. We can calculate the speed of the motor by the gear ratio.

$$i_{12} = \frac{\omega_1}{\omega_2} = \frac{r_2'}{r_1'}$$

$$\omega_1 = \omega_2 \frac{r_2'}{r_1'}$$

Where $r_2' = 11.5cm$, $r_1' = 0.8cm$, the equation of w2 is given above. Then we can get the angular velocity of the motor.

$$\omega = -0.0786t^3 + 0.5023t^2 - 1.238t + 4.8013 \quad (0s < t \le 2.1s)$$

$$\omega = -0.0779t^3 - 0.4827t^2 + 1.1629t + 2.6536 \quad (2.1s < t \le 4.2s)$$

7.2 Method 2: Improved method

7.2.1 Establishment of kinematics equation

We can get the expression of the angle of the active arm by moving the glass, and then get the angular velocity of the active arm.

7.2.2 Assumptions

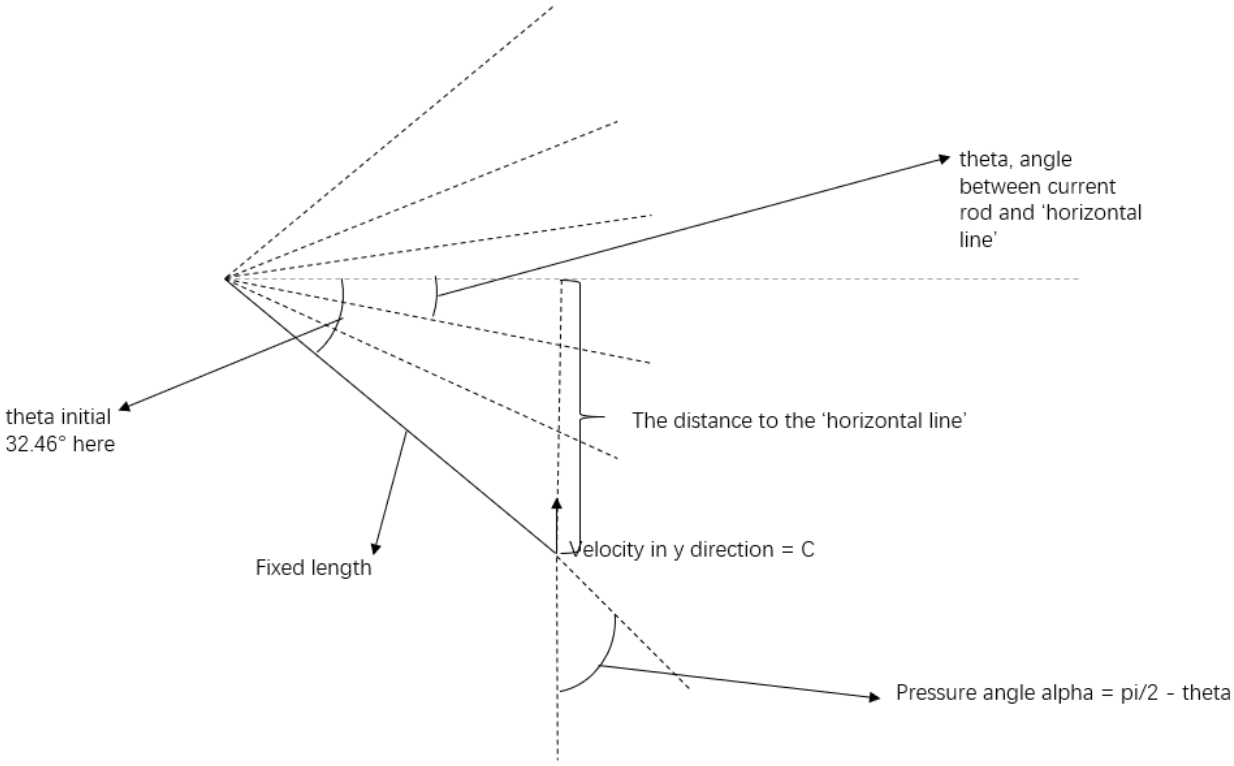
1. The rising speed of glass remains constant.

2. The rising process of glass is symmetrical about the fulcrum of active arm.

3. Only one degree of freedom motion is considered

7.2.3 Data measurement

1. Length of driving arm is 34cm by measurement
2. Window height is 36.5cm from Internet
3. Window moving up time is 4.2s from Internet



According to the velocity analysis, we get the following equation, where V is the constant and equals to 0.0869 m/s and h is the height of the window.

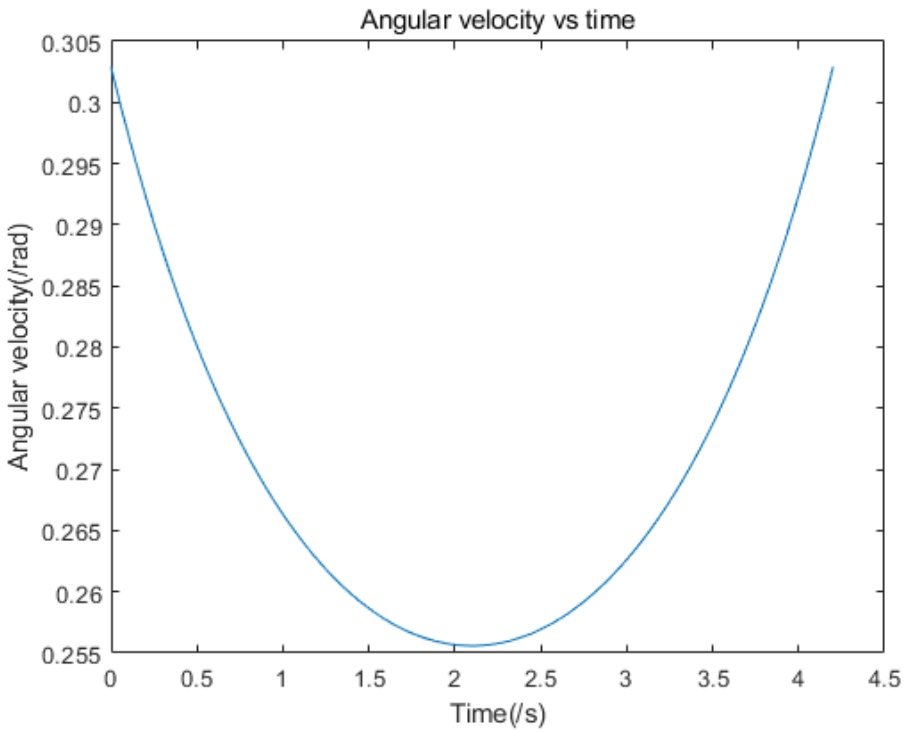
$$\sin\theta = \frac{abs(Vt - \frac{h}{2})}{L}$$

Then,

$$\theta = \text{asin}(\frac{abs(Vt - \frac{h}{2})}{L})$$

We can get the angular velocity from the equation of the angle.

$$\omega = \dot{\theta} = \frac{\frac{V}{L}}{\sqrt{1 - \left[\frac{abs(Vt - \frac{h}{2})}{L}\right]^2}}$$



7.3 Motor power selection

$$P = Fv = (mg + \mu mg)v$$

Where $\mu = 0.7$ from the Internet, V is the constant which equals to

0.0869 m/s, The gravity of the glass is about 3.5kg. Then we can get the power is about 5W.

7.4 Calculation of pressure angle

From method two, we get the formula of the pressure angle

$$\alpha = \frac{\pi}{2} - \theta = \frac{\pi}{2} - \text{asin}\left(\frac{abs(Vt - \frac{h}{2})}{L}\right)$$