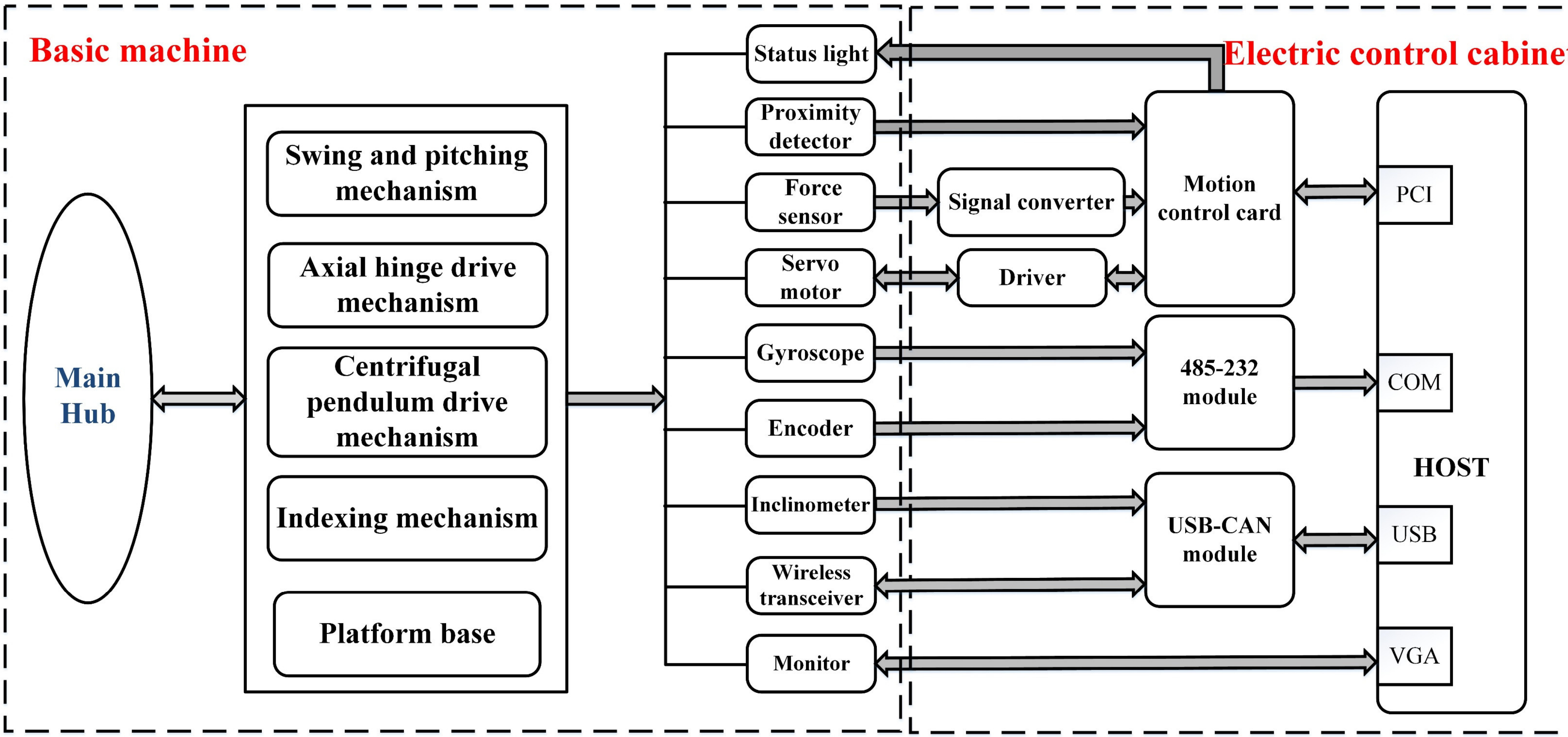
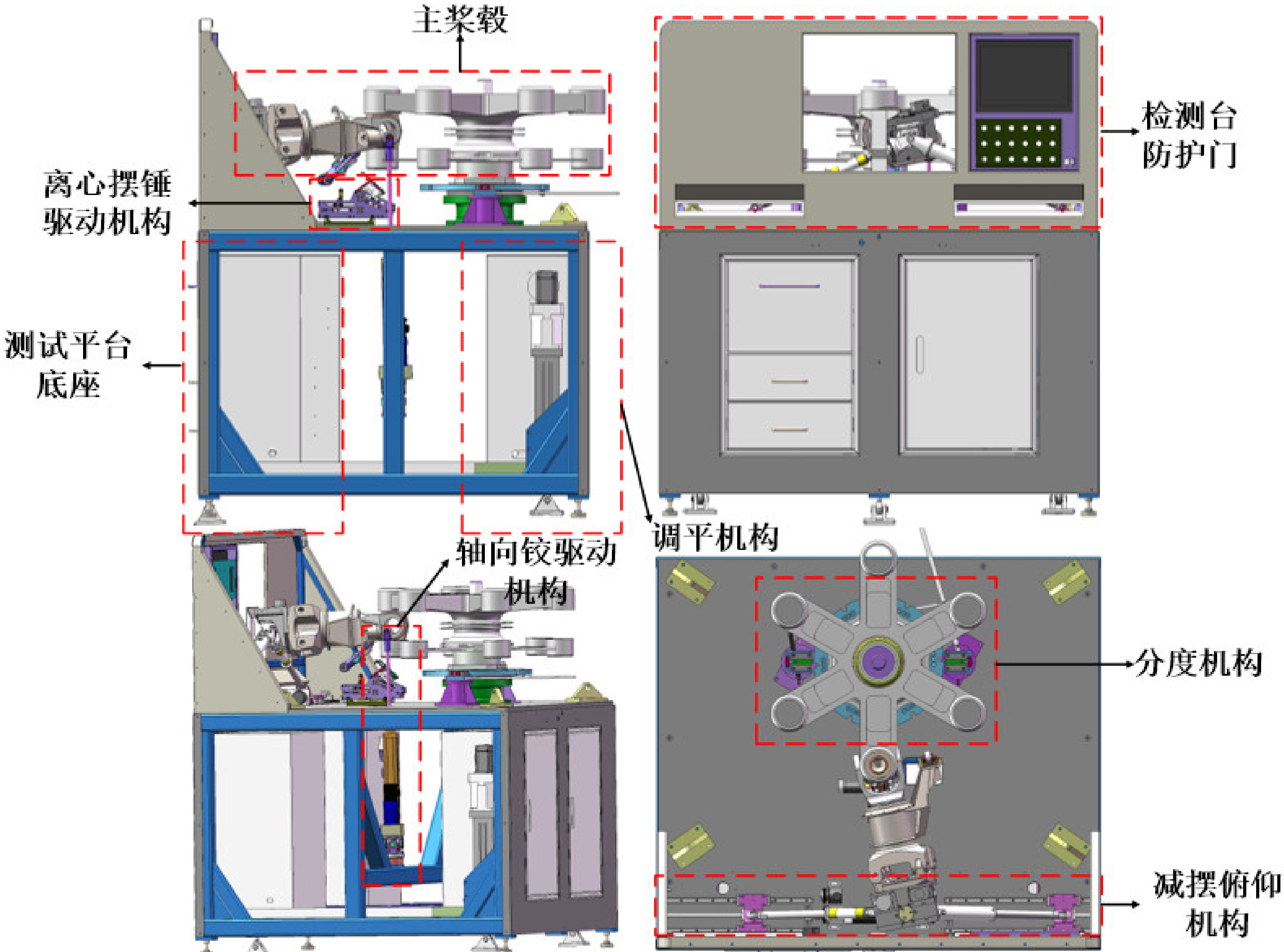
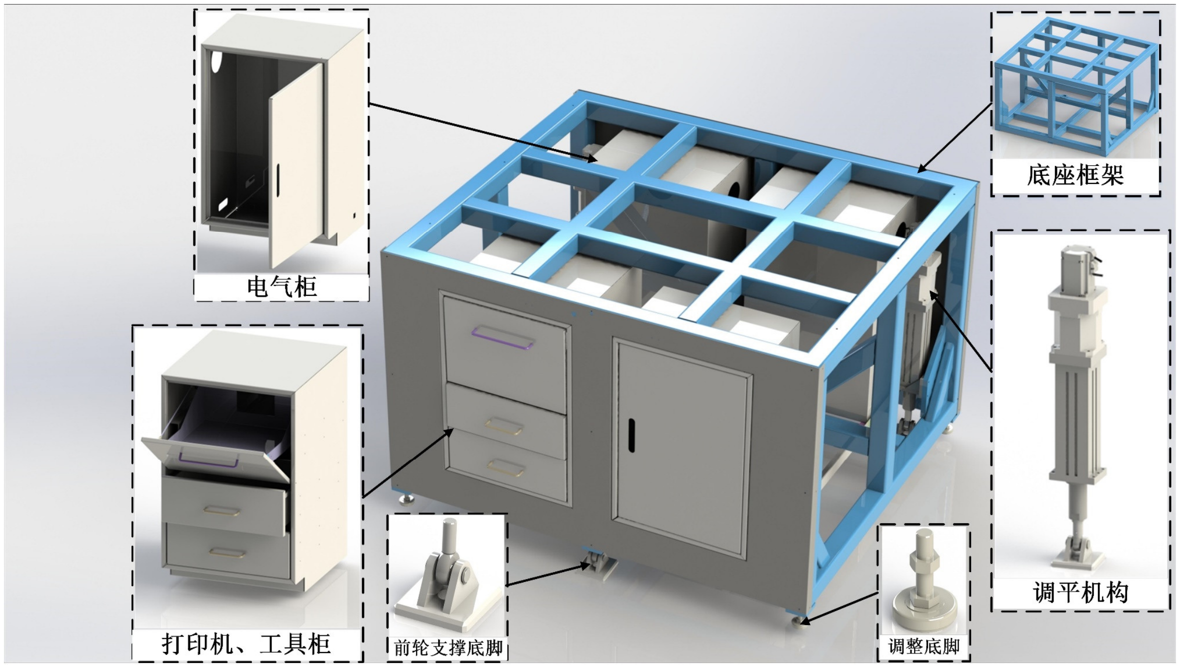
Overall design---design of the mechanical structure and control system

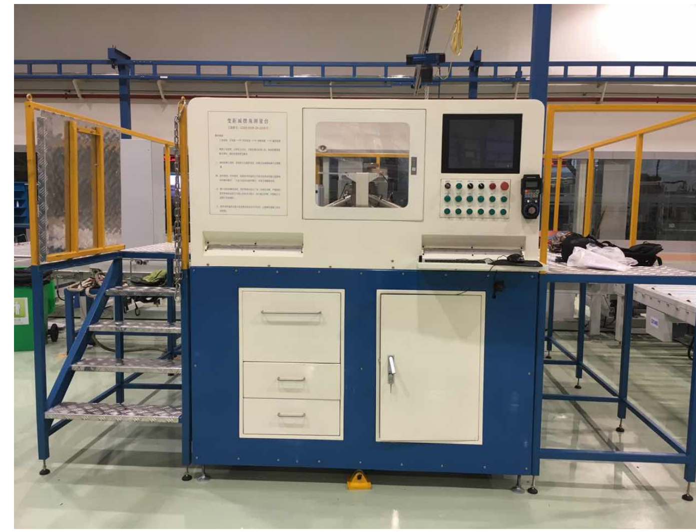


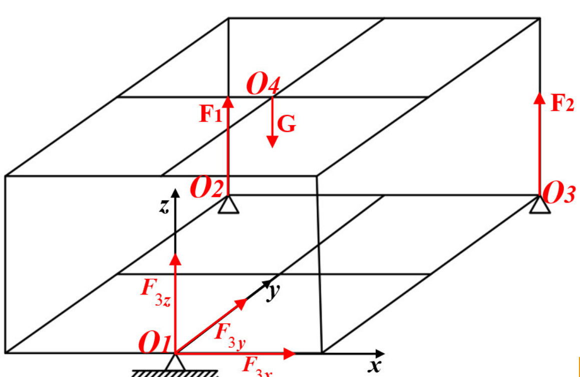
3D model of measuring platform

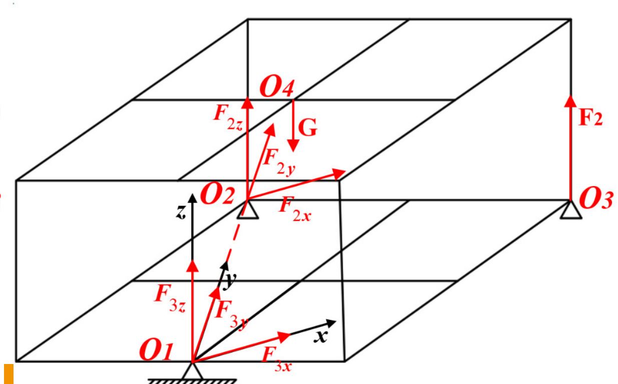


Platform base – Ensure horizontal working plane

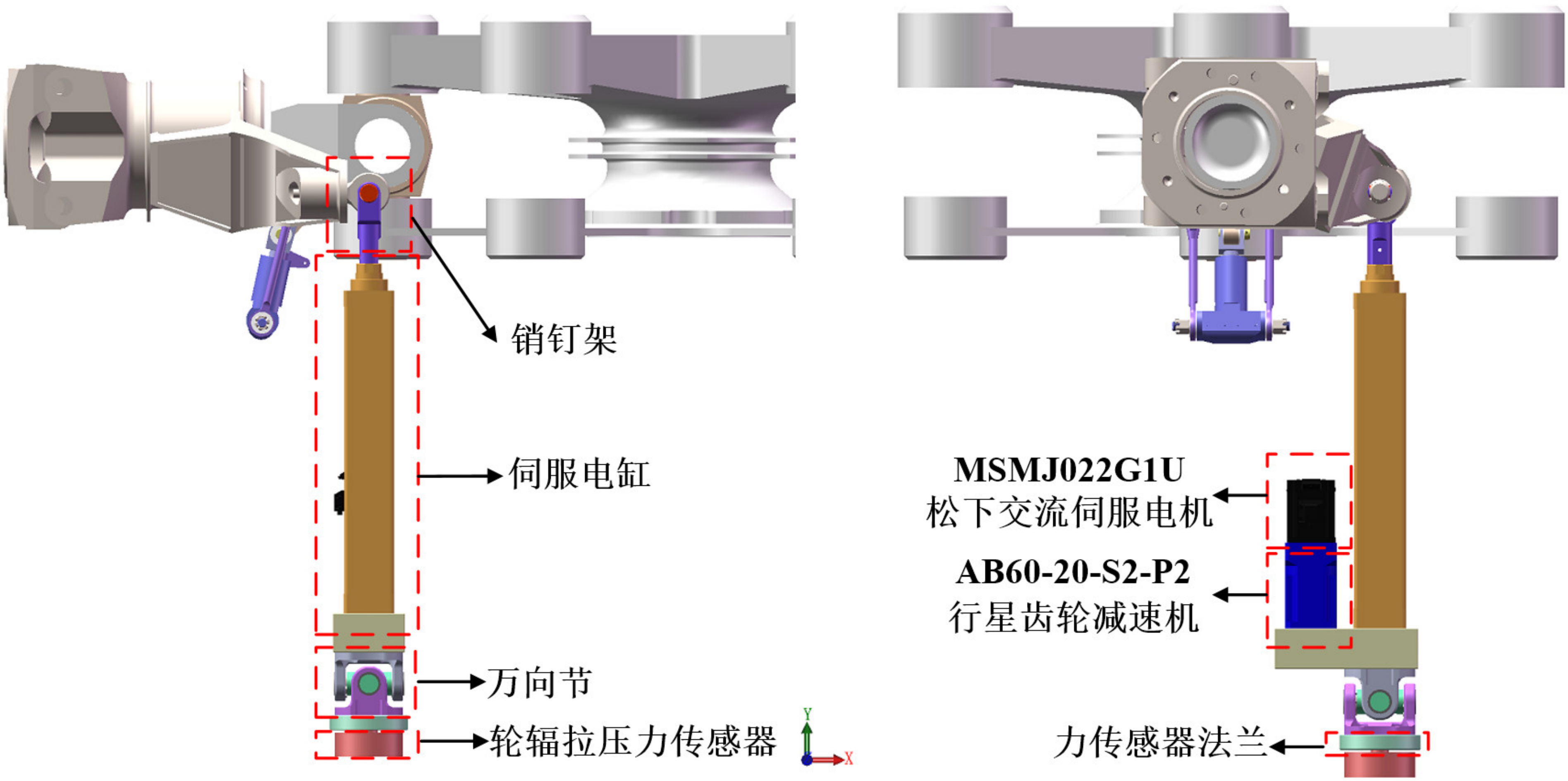




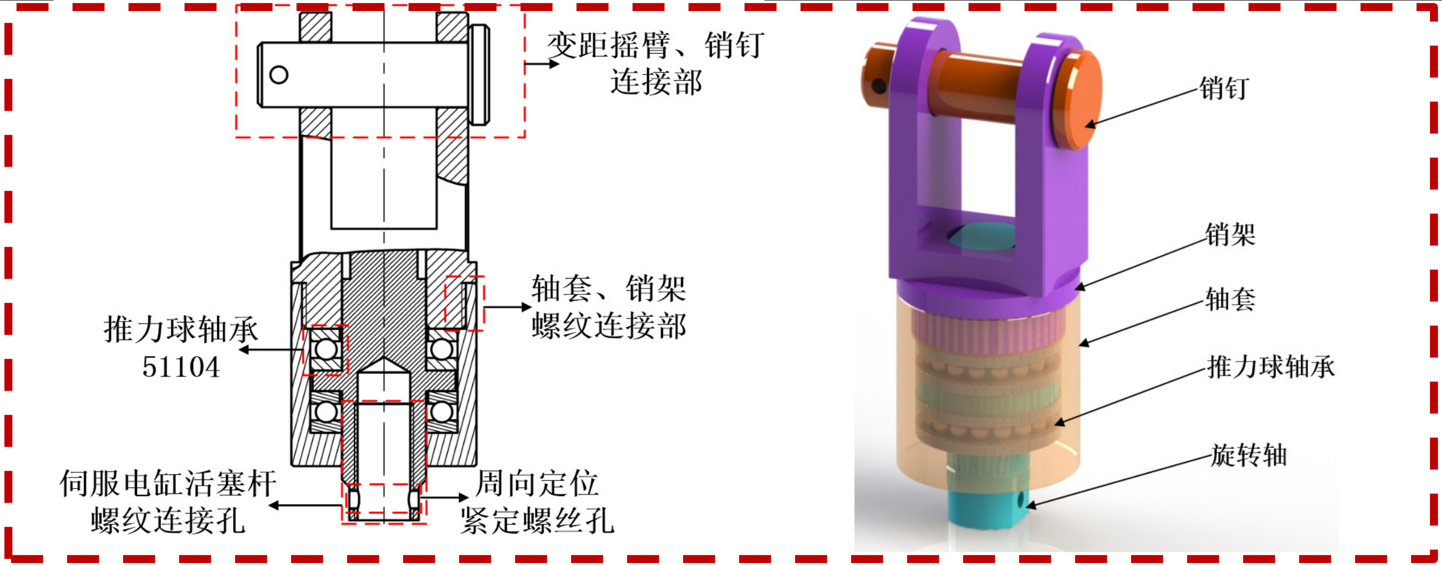


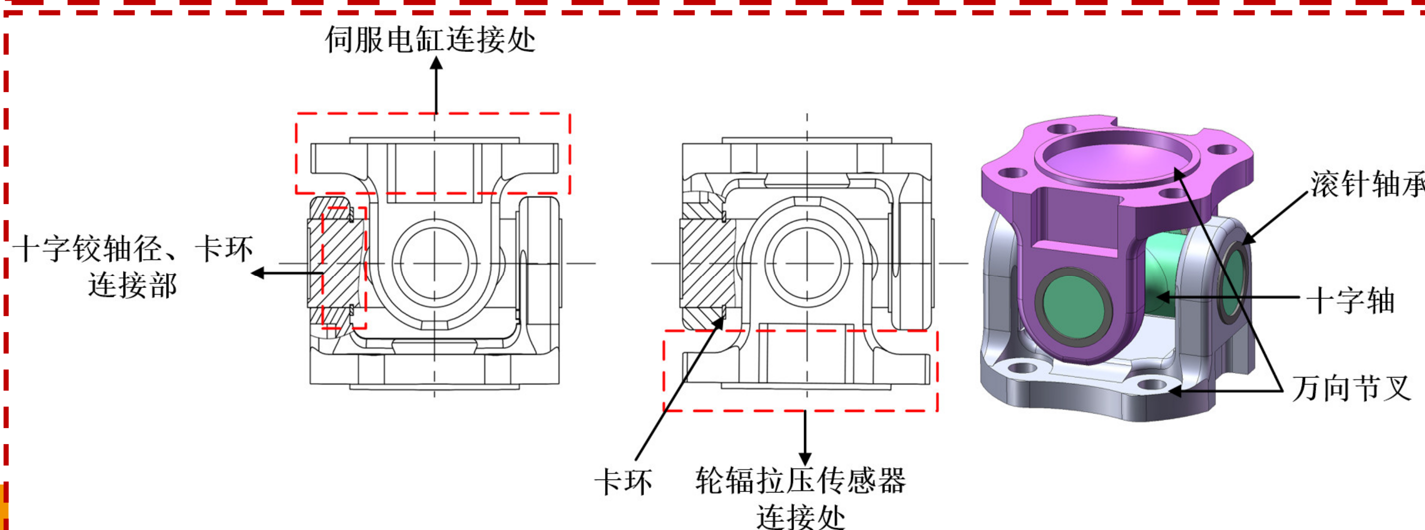


Axial hinge drive mechanism – Variable pitch angle

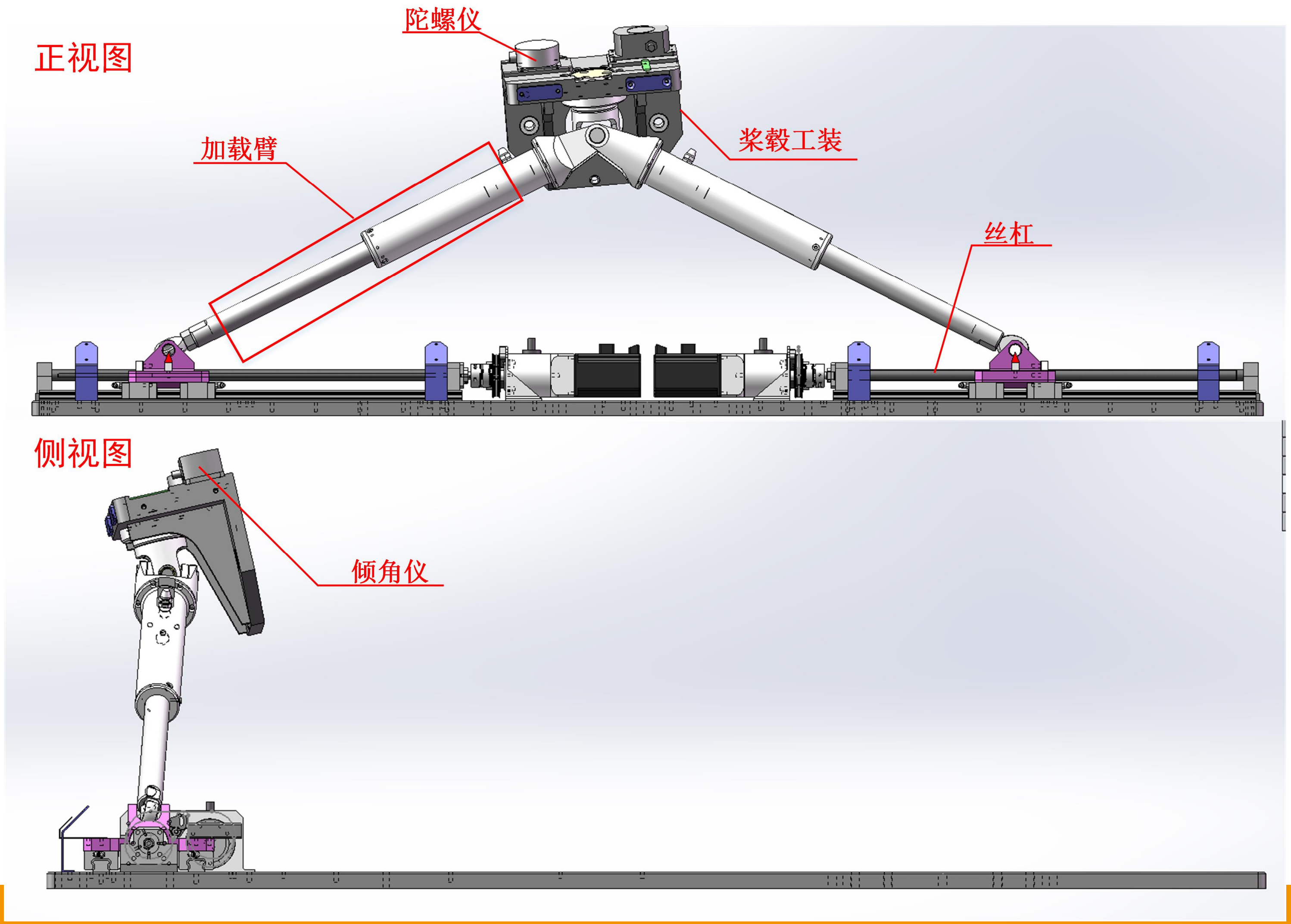


Axial hinge drive mechanism – Pin rack and cardan joint

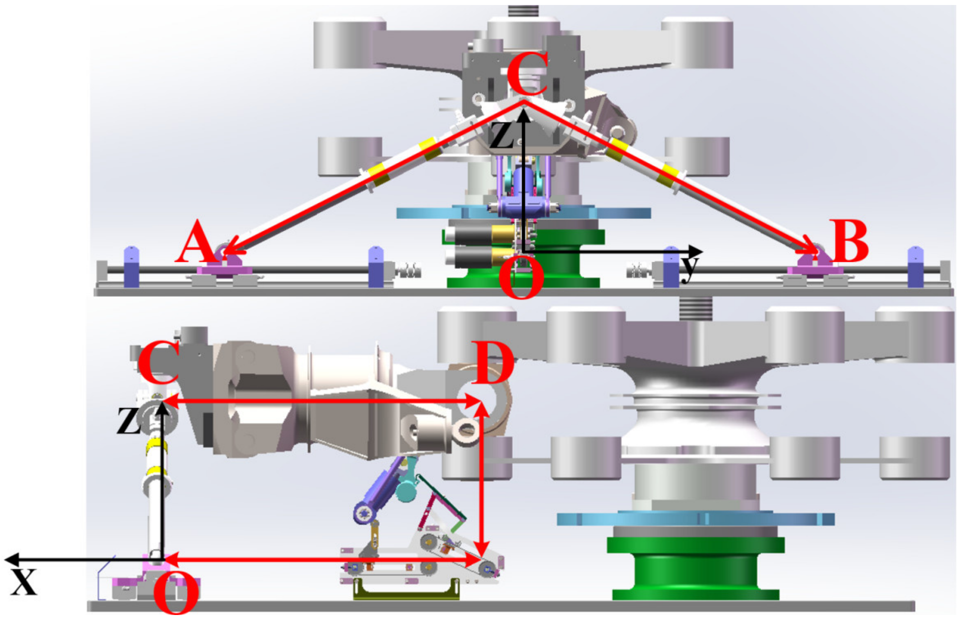


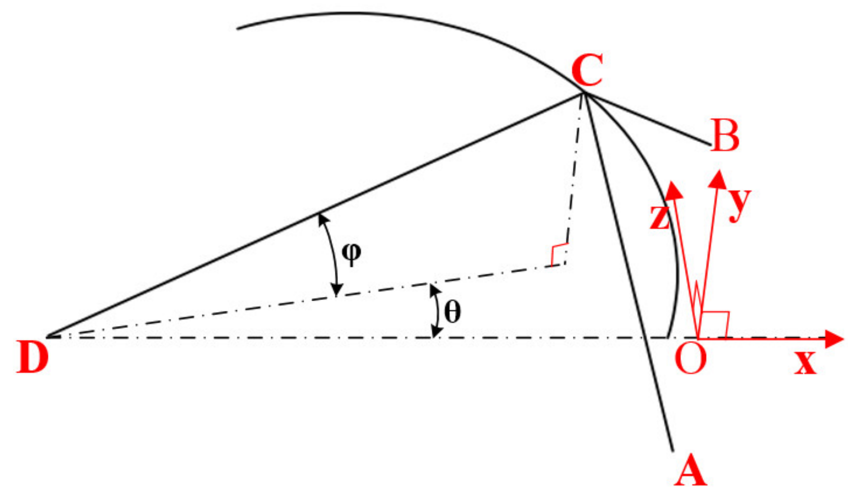


Swing and pitching mechanism – Pitching angle and swing angle



Swing and pitching mechanism – Kinematics





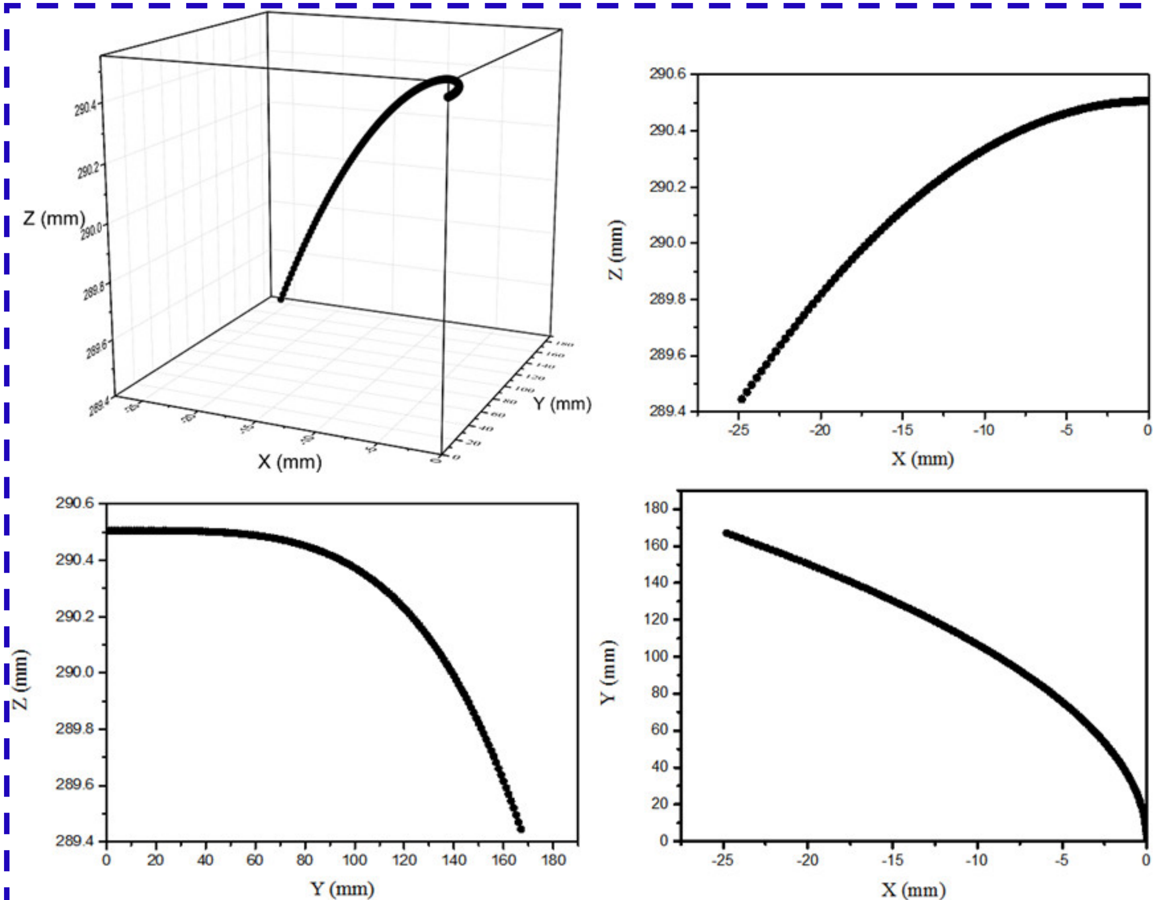
$$\begin{cases}(C_x-A_x)^2+\left(C_y-A_y\right)^2+\left(C_z-A_z\right)^2=R_1^{\,2}\\(C_x-B_x)^2+\left(C_y-B_y\right)^2+\left(C_z-B_z\right)^2=R_2^{\,2}\\(C_x-D_x)^2+\left(C_y-D_y\right)^2+\left(C_z-D_z\right)^2=R_3^{\,2}\end{cases}$$

$$\begin{cases}\varphi=a\sin\left(\dfrac{C_z-D_z}{R_3}\right)\\ \theta=\left(\dfrac{C_y}{R_3\cos(\varphi)}\right)\end{cases}$$

$$\left(C_x,C_y,C_z\right)=(\cos(\varphi)R_3\cos(\theta)+D_x,\cos(\varphi)R_3\sin(\theta),D_z+R_3\sin(\varphi))$$

Swing Kinematics Analysis

(a) Motion Trajectory Simulation

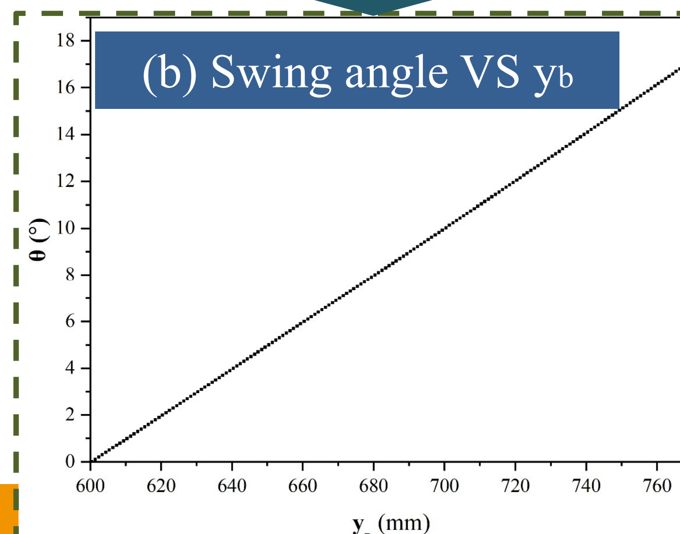


$$B_y - A_y = B_{y0} - A_{y0}$$

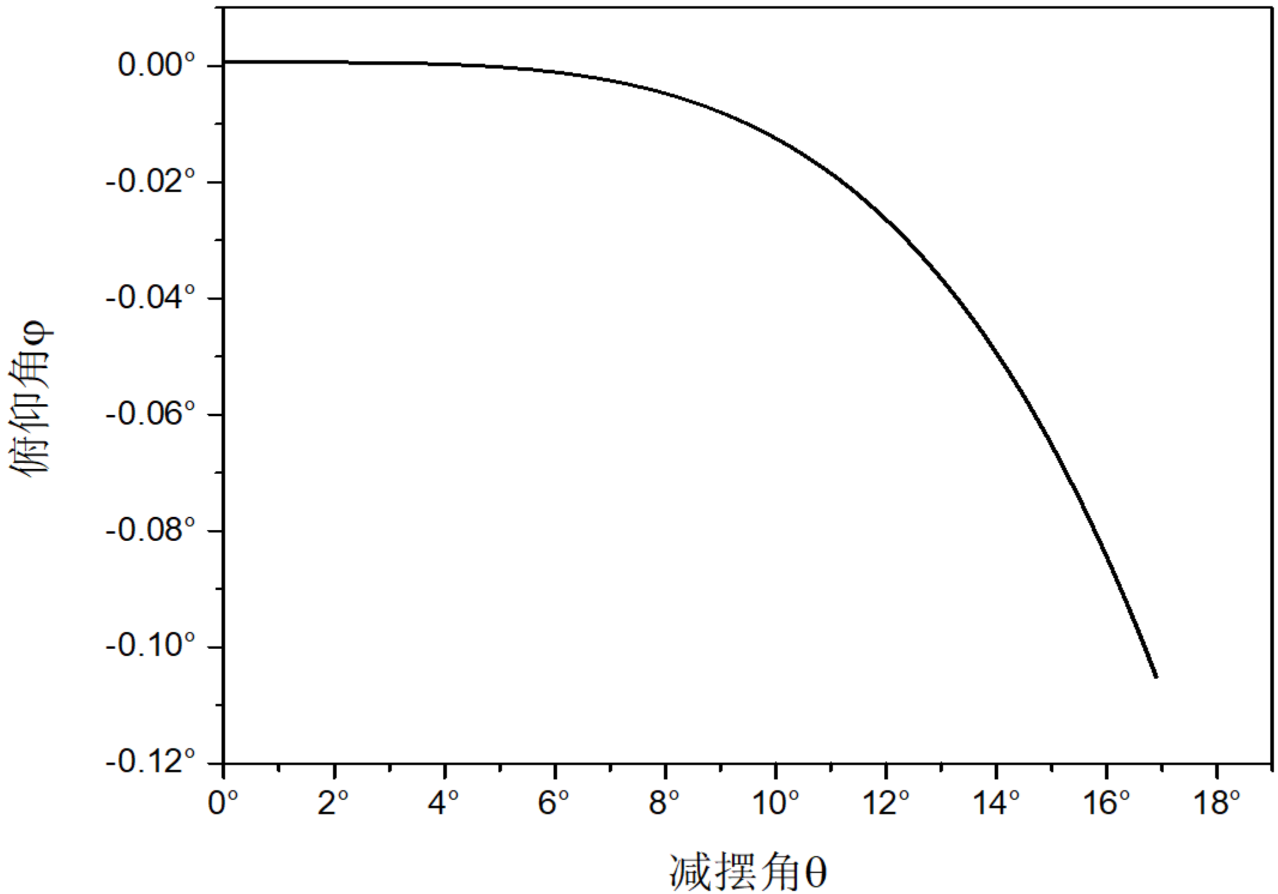
$$\begin{cases} (C_x - A_x)^2 + (C_y - A_y)^2 + (C_z - A_z)^2 = R_1^2 \\ (C_x - B_x)^2 + (C_y - B_y)^2 + (C_z - B_z)^2 = R_2^2 \\ (C_x - D_x)^2 + (C_y - D_y)^2 + (C_z - D_z)^2 = R_3^2 \end{cases}$$

$$\begin{cases} \varphi = a\sin\left(\frac{C_z - D_z}{R_3}\right) \\ \theta = \left(\frac{C_y}{R_3\cos(\varphi)}\right) \end{cases}$$

(b) Swing angle VS yb

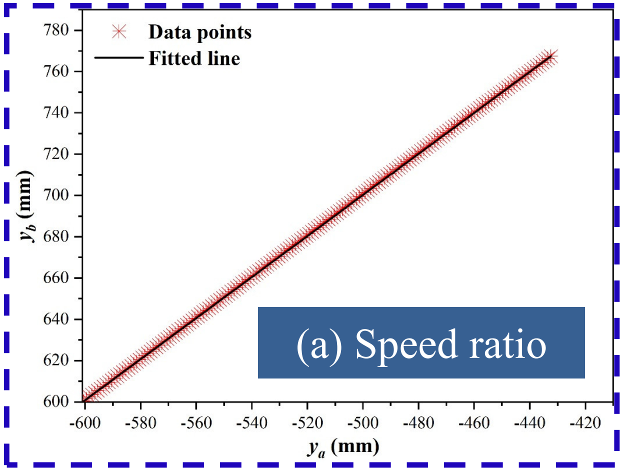


Swing Kinematics Analysis

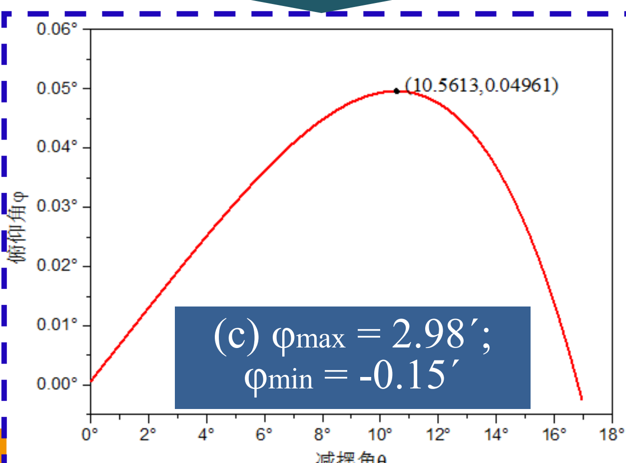


When the swing angle θ changes within the range of 0 ~ 16.89°, the pitching angle φ will correspondingly drop from 0 to -0.105° (-6.3′)

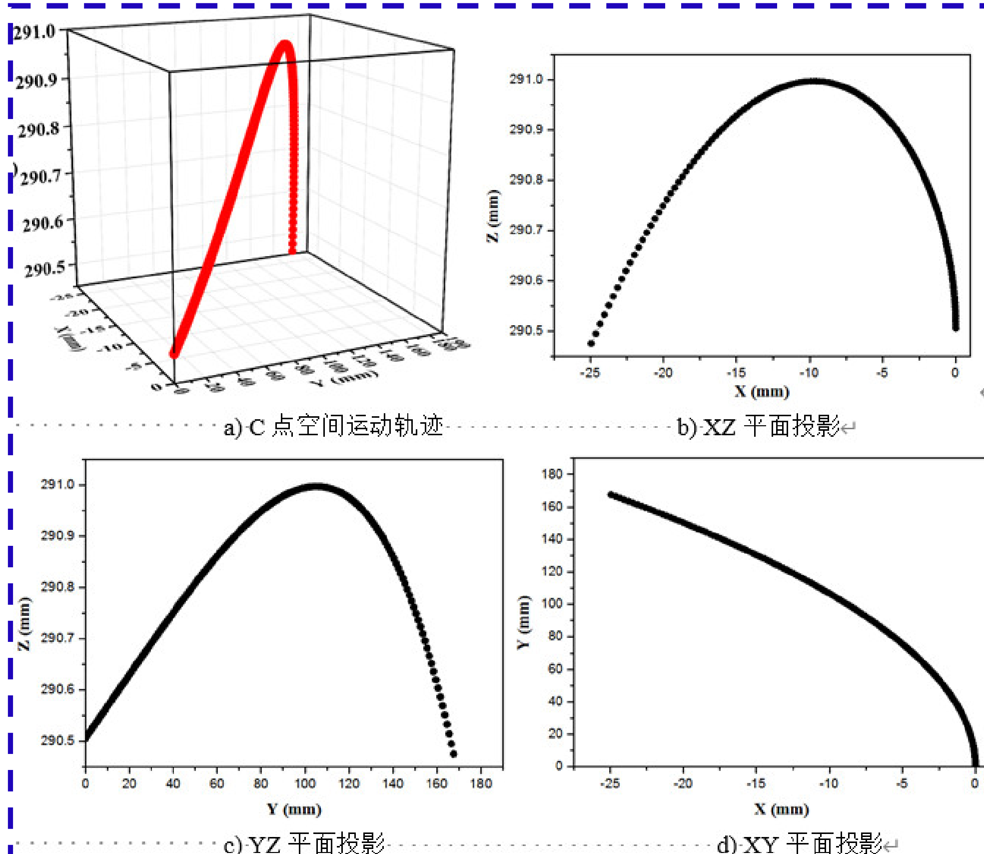
Control error within ±5′ -- Electronic gear



$$y_b = 0.994\, y_a + 1197.2225 \qquad \frac{v_B}{v_A} = 0.9946$$

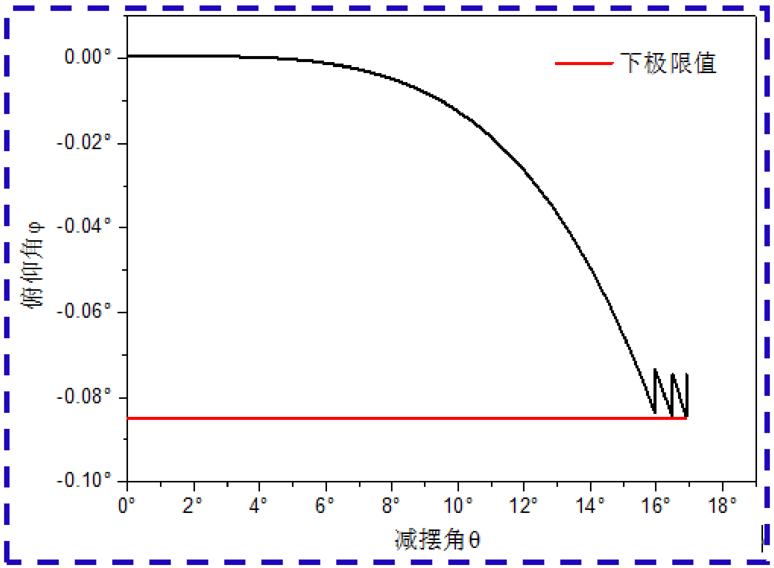


(b) Motion Trajectory using electronic gear

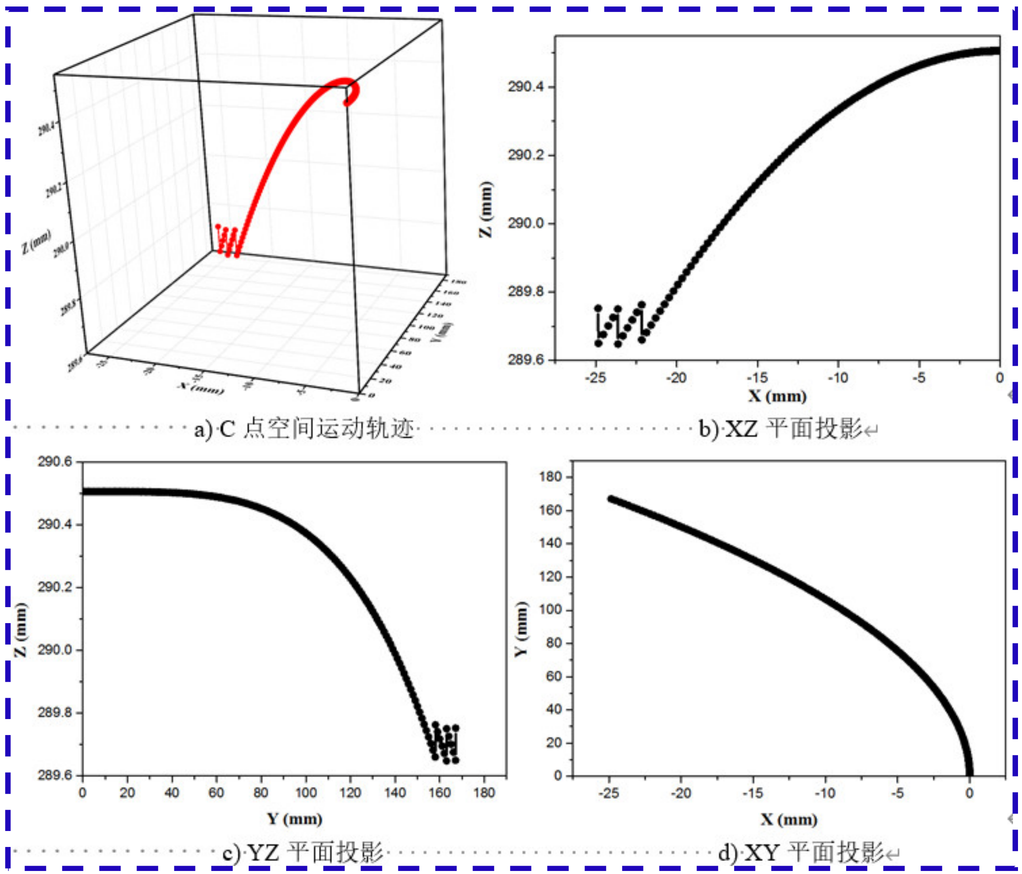


Control error within ±5′ -- Feedback correction

(a) When the limit is exceeded, slider A is fine-tuned to the right by 0.1mm

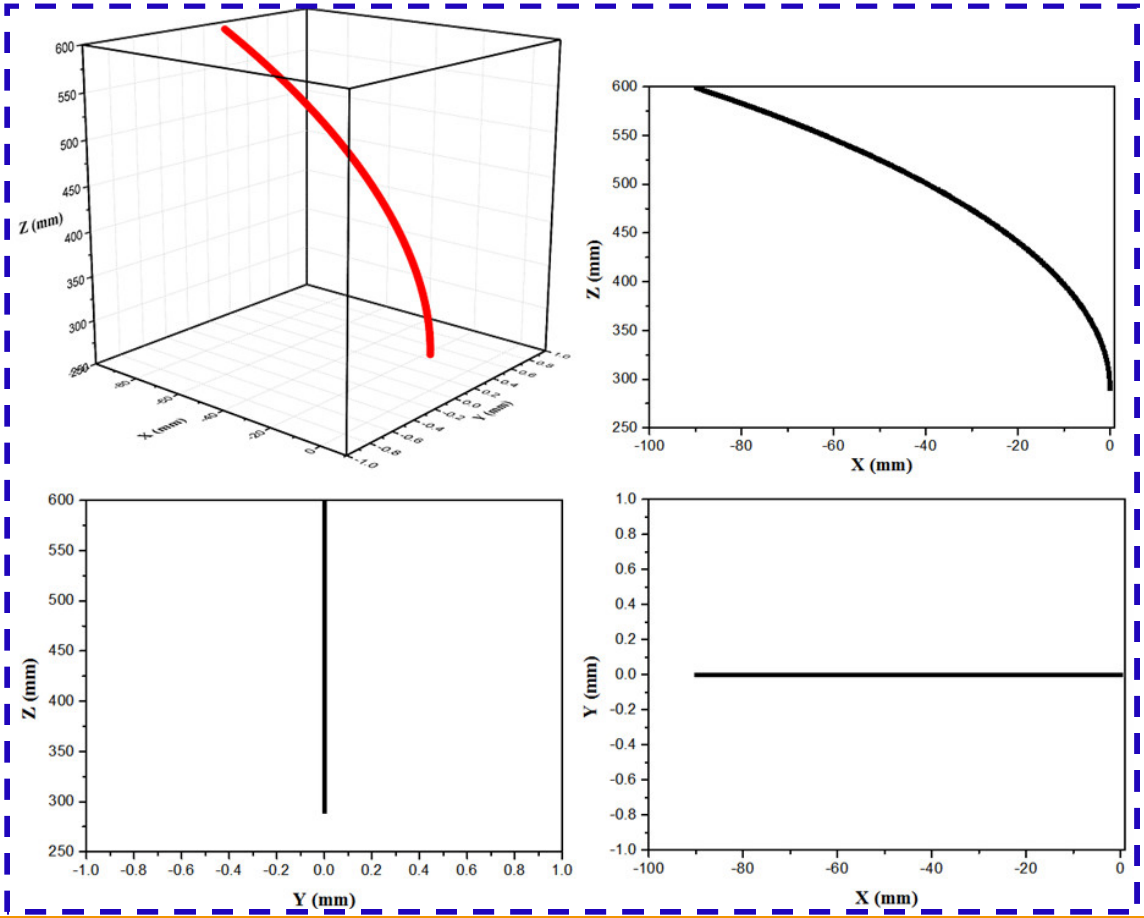


(b) Motion Trajectory using feedback correction



Pitching Kinematics Analysis

(a) Motion Trajectory Simulation

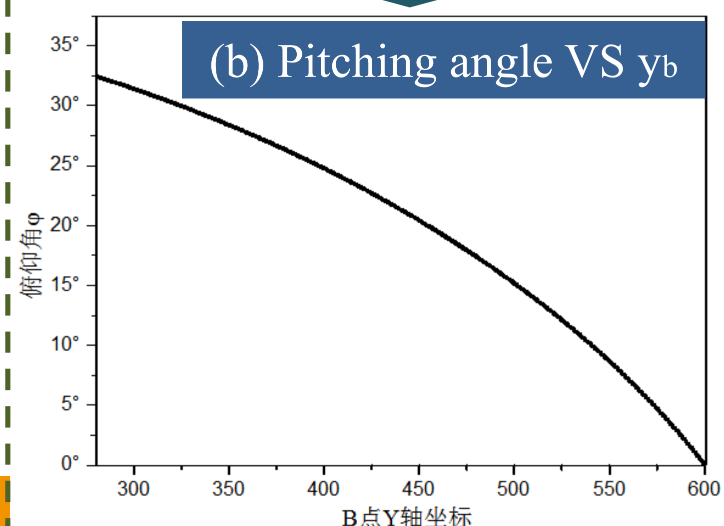


$$B_y - A_y = B_{y0} - A_{y0}$$

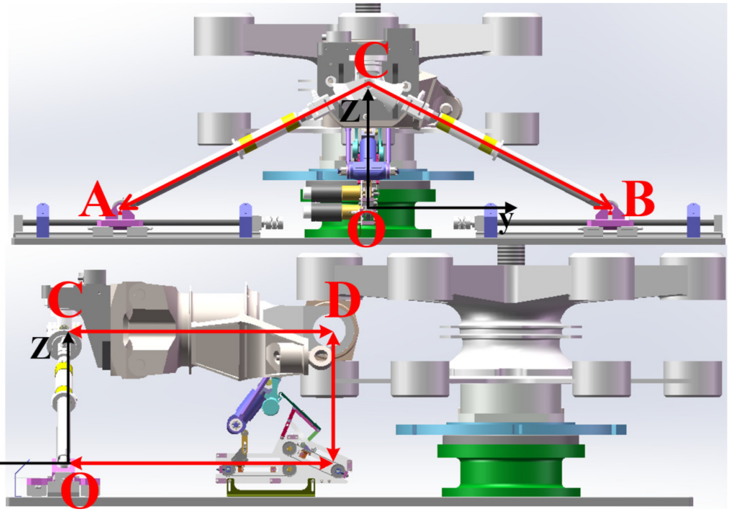
$$\begin{cases} (C_x - A_x)^2 + \left(C_y - A_y\right)^2 + \left(C_z - A_z\right)^2 = R_1^2 \\ (C_x - B_x)^2 + \left(C_y - B_y\right)^2 + \left(C_z - B_z\right)^2 = R_2^2 \\ (C_x - D_x)^2 + \left(C_y - D_y\right)^2 + \left(C_z - D_z\right)^2 = R_3^2 \end{cases}$$

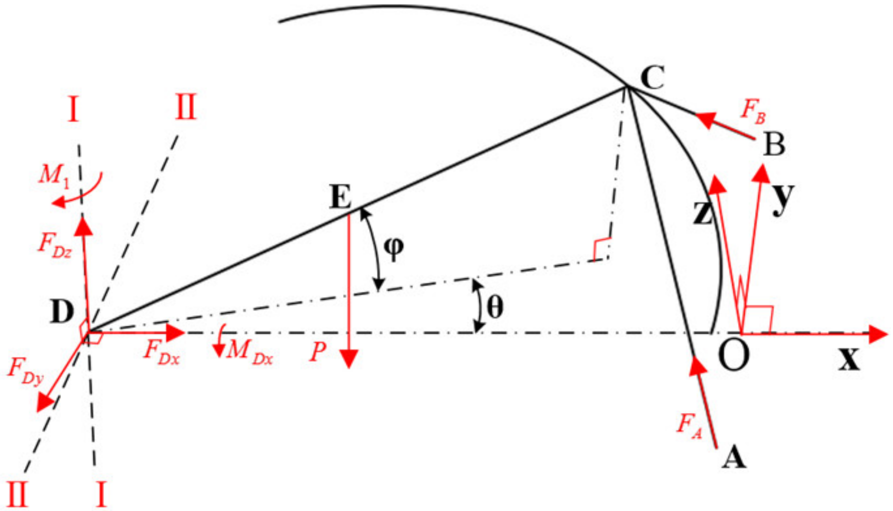
$$\begin{cases} \varphi = a\sin\left(\frac{C_z - D_z}{R_3}\right) \\ \boldsymbol{\theta} = \left(\frac{C_y}{R_3 \cos(\varphi)}\right) \end{cases}$$

(b) Pitching angle VS y_b



Swing and pitching mechanism – Statics





$$
\begin{cases}
\Sigma F_x = 0, \quad F_{Dx} + \dfrac{F_A dot(\overrightarrow{AC}, \vec{i})}{|\overrightarrow{AC}|} + \dfrac{F_B dot(\overrightarrow{BC}, \vec{i})}{|\overrightarrow{BC}|} = 0 \\
\Sigma F_y = 0, \quad -F_{Dy} + \dfrac{F_A dot(\overrightarrow{AC}, \vec{j})}{|\overrightarrow{AC}|} + \dfrac{F_B dot(\overrightarrow{BC}, \vec{j})}{|\overrightarrow{BC}|} = 0 \\
\Sigma F_z = 0, \quad F_{Dz} + \dfrac{F_A dot(\overrightarrow{AC}, \vec{k})}{|\overrightarrow{AC}|} + \dfrac{F_B dot(\overrightarrow{BC}, \vec{k})}{|\overrightarrow{BC}|} - P = 0 \\
\overrightarrow{M_D} = \overrightarrow{DA} \times \overrightarrow{F_A} + \overrightarrow{DB} \times \overrightarrow{F_B} + \overrightarrow{DE} \times \vec{P} + \overrightarrow{M_1} + \overrightarrow{M_{Dx}} = \vec{0}
\end{cases}
$$

dot($\vec{a}, \vec{b}$)——$\vec{a}$、$\vec{b}$ 的数量积；

$|\vec{a}|$——$\vec{a}$ 的模长，（mm）；

F_A——A 点受到的约束力，即杆 AC 轴向力，（kgf）；

F_B——B 点受到的约束力，即杆 BC 轴向力，（kgf）；

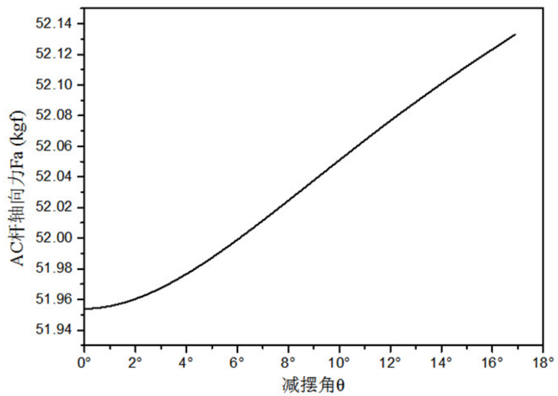
$F_{Dx}, F_{Dy}, F_{Dz}, M_{Dx}$——D 点万向接头提供的约束力；

M_1——液压减摆器的阻尼力矩，（kgf·mm）。

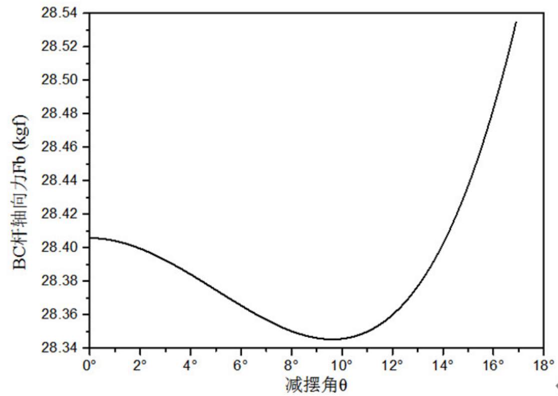
$$
\begin{cases}
F_A \\ F_B \\ F_{Dx} \\ F_{Dy} \\ F_{Dz} \\ M_{Dx}
\end{cases}
$$

Swing and pitching mechanism – Statics

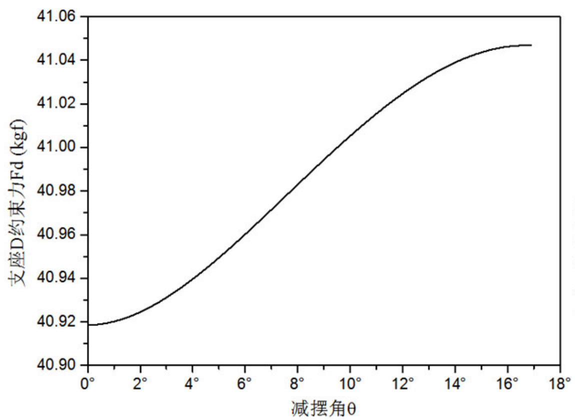
(a) Forces VS swing angle



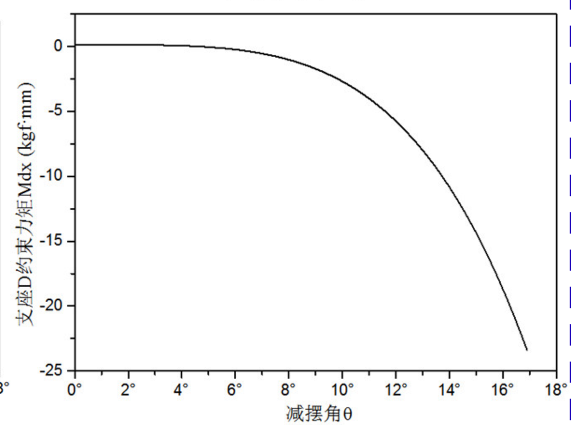
a) 轴向力 F_a



b) 轴向力 F_b



c) 基座约束反力合力 F_d



d) 基座约束力矩 M_{dx}

$$
\begin{cases}
\Sigma F_x = 0, \quad F_{Dx} + \dfrac{F_A dot(\overrightarrow{AC},\vec{i})}{|\overrightarrow{AC}|} + \dfrac{F_B dot(\overrightarrow{BC},\vec{i})}{|\overrightarrow{BC}|} = 0 \\
\Sigma F_y = 0, \quad -F_{Dy} + \dfrac{F_A dot(\overrightarrow{AC},\vec{j})}{|\overrightarrow{AC}|} + \dfrac{F_B dot(\overrightarrow{BC},\vec{j})}{|\overrightarrow{BC}|} = 0 \\
\Sigma F_z = 0, \quad F_{Dz} + \dfrac{F_A dot(\overrightarrow{AC},\vec{k})}{|\overrightarrow{AC}|} + \dfrac{F_B dot(\overrightarrow{BC},\vec{k})}{|\overrightarrow{BC}|} - P = 0 \\
\overrightarrow{M_D} = \overrightarrow{DA} \times \overrightarrow{F_A} + \overrightarrow{DB} \times \overrightarrow{F_B} + \overrightarrow{DE} \times \vec{P} + \overrightarrow{M_1} + \overrightarrow{M_{Dx}} = \vec{0}
\end{cases}
$$

$$
\begin{cases}
(F_a)_{\max} = 52.1329kgf \\
(F_b)_{\max} = 28.5346kgf \\
(F_D)_{\max} = 41.0468kgf \\
(M_{Dx})_{\max} = -22.7823kgf \bullet mm
\end{cases}
$$

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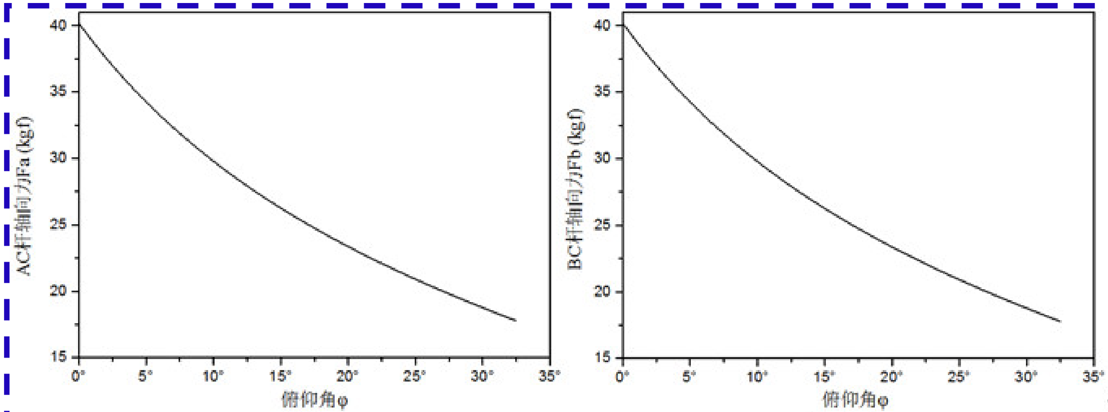
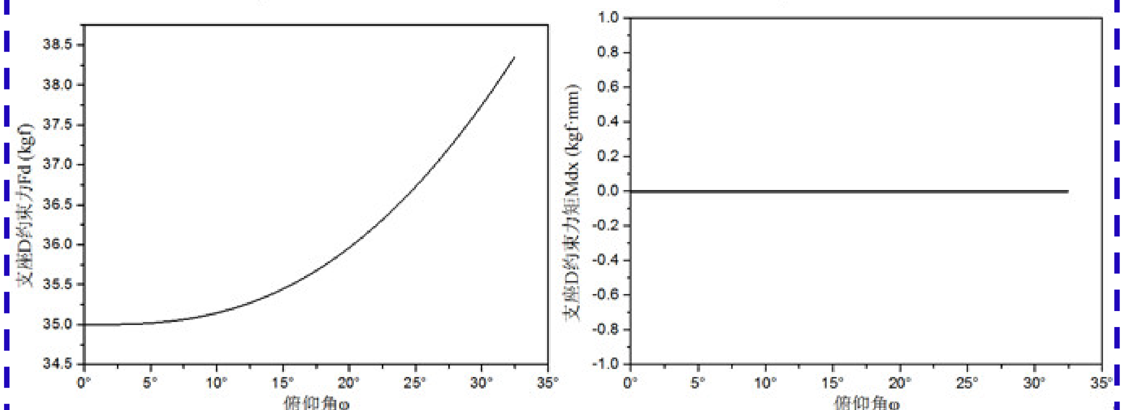
Swing and pitching mechanism – Statics

(a) Forces VS pitching angle



a) 轴向力 F_a b) 轴向力 F_b

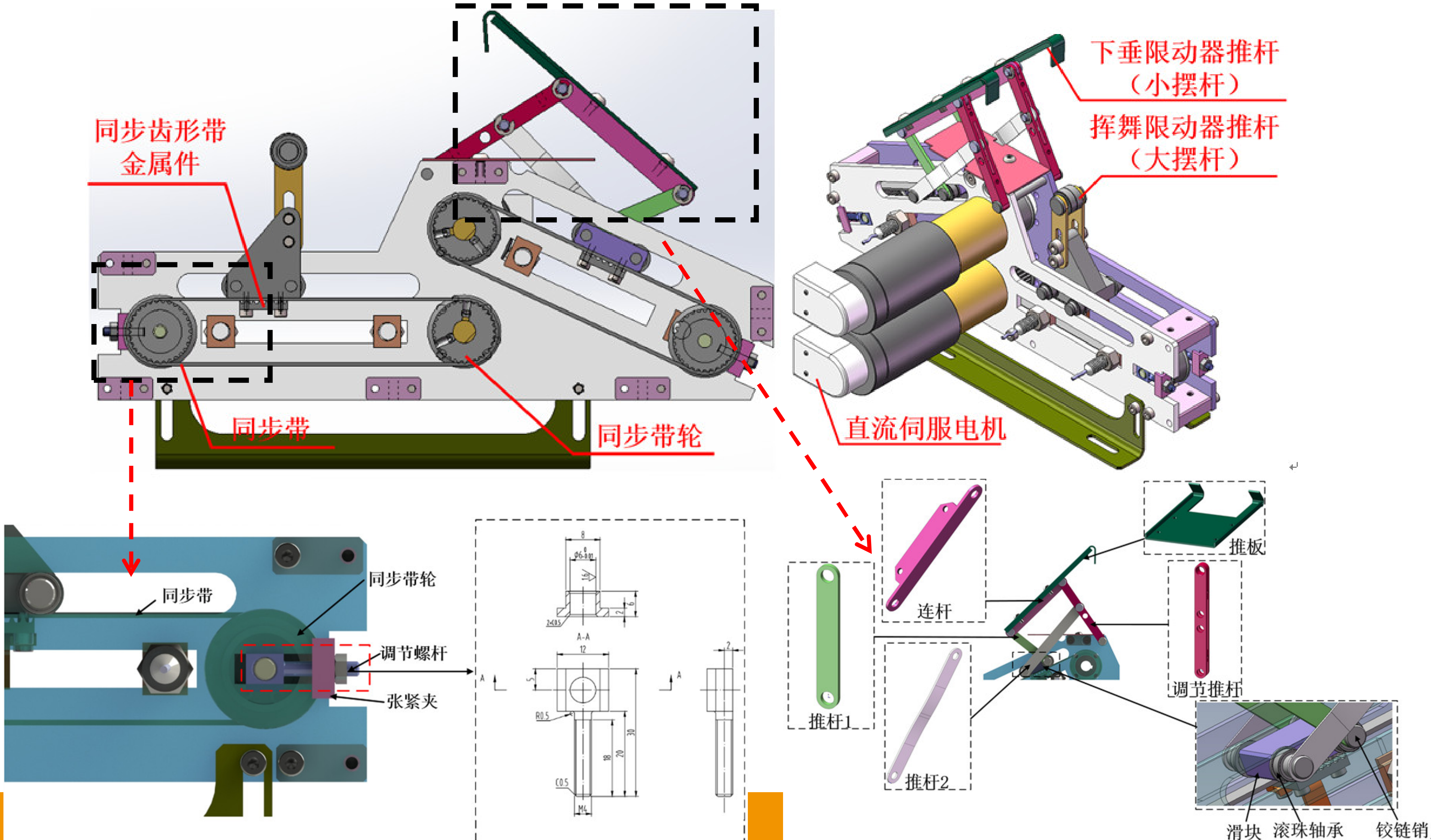


c) 基座约束反力合力 F_d d) 基座约束力矩 M_{dx}

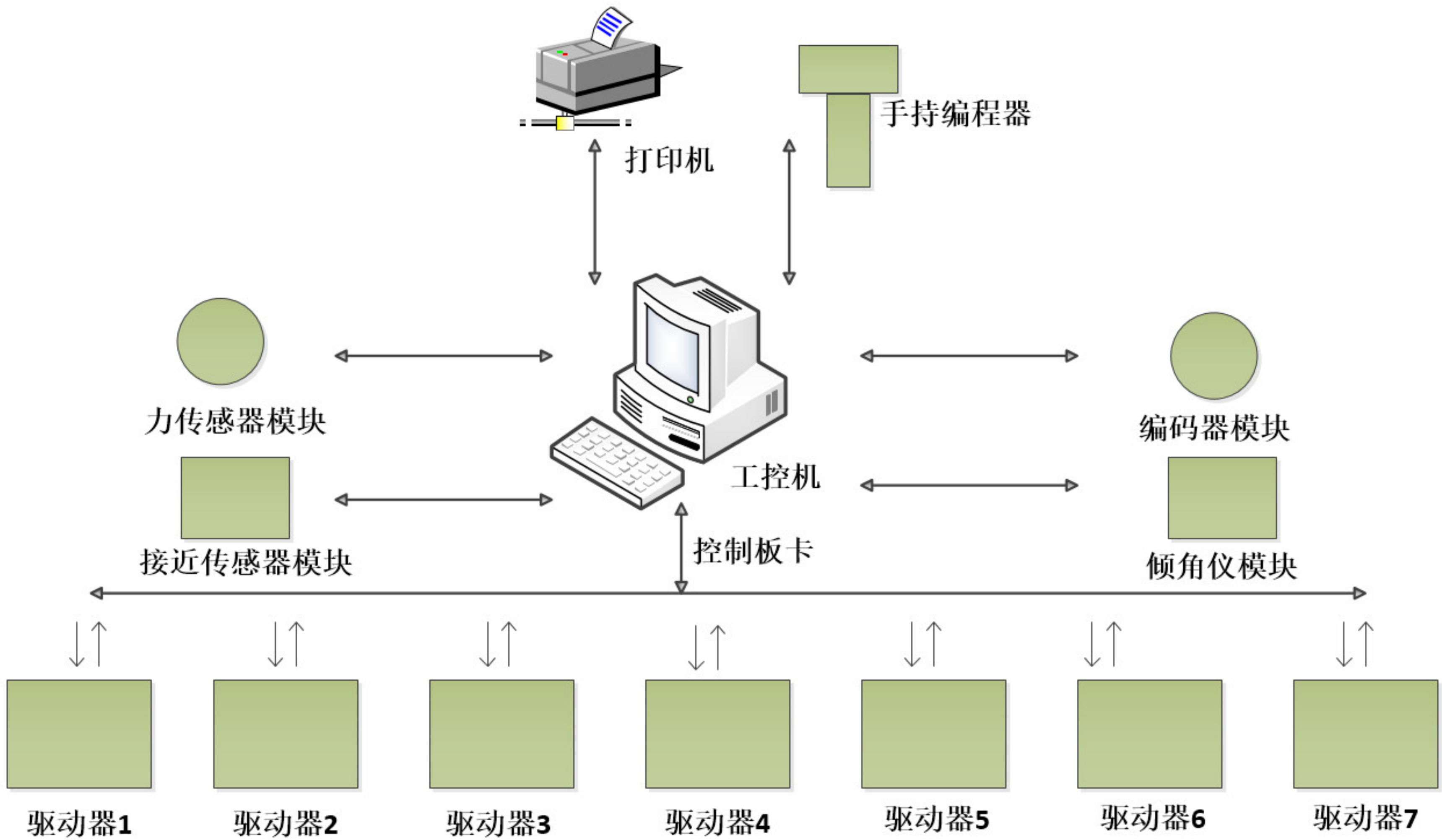
$$
\begin{cases}
\Sigma F_x = 0, \quad F_{Dx} + \dfrac{F_A dot(\overrightarrow{AC},\vec{i})}{\left|\overrightarrow{AC}\right|} + \dfrac{F_B dot(\overrightarrow{BC},\vec{i})}{\left|\overrightarrow{BC}\right|} = 0 \\
\Sigma F_y = 0, \quad -F_{Dy} + \dfrac{F_A dot(\overrightarrow{AC},\vec{j})}{\left|\overrightarrow{AC}\right|} + \dfrac{F_B dot(\overrightarrow{BC},\vec{j})}{\left|\overrightarrow{BC}\right|} = 0 \\
\Sigma F_z = 0, \quad F_{Dz} + \dfrac{F_A dot(\overrightarrow{AC},\vec{k})}{\left|\overrightarrow{AC}\right|} + \dfrac{F_B dot(\overrightarrow{BC},\vec{k})}{\left|\overrightarrow{BC}\right|} - P = 0 \\
\overrightarrow{M_D} = \overrightarrow{DA} \times \overrightarrow{F_A} + \overrightarrow{DB} \times \overrightarrow{F_B} + \overrightarrow{DE} \times \vec{P} + \overrightarrow{M_1} + \overrightarrow{M_{Dx}} = \vec{0}
\end{cases}
$$

$$
\begin{cases}
(F_a)_{\max} = 40.1799kgf \\
(F_b)_{\max} = 40.1799kgf \\
(F_D)_{\max} = 38.3498kgf \\
M_{Dx} = 0
\end{cases}
$$

Centrifugal pendulum drive mechanism



Control system scheme



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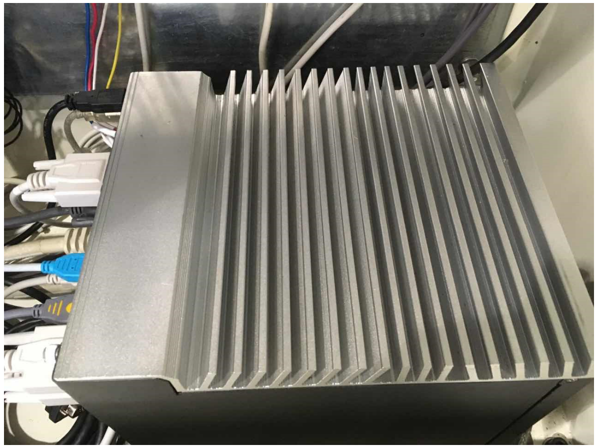
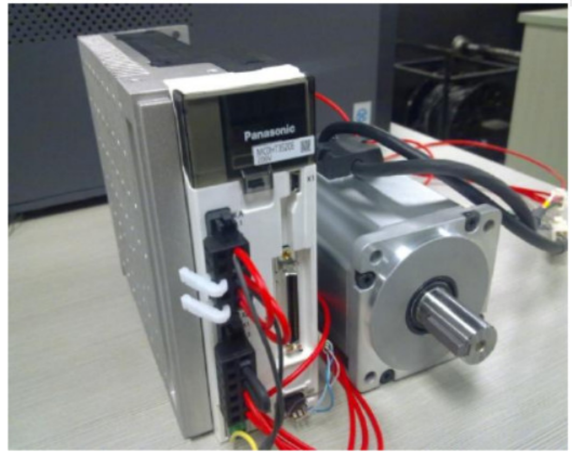
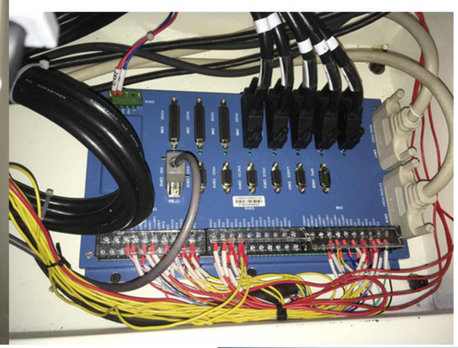






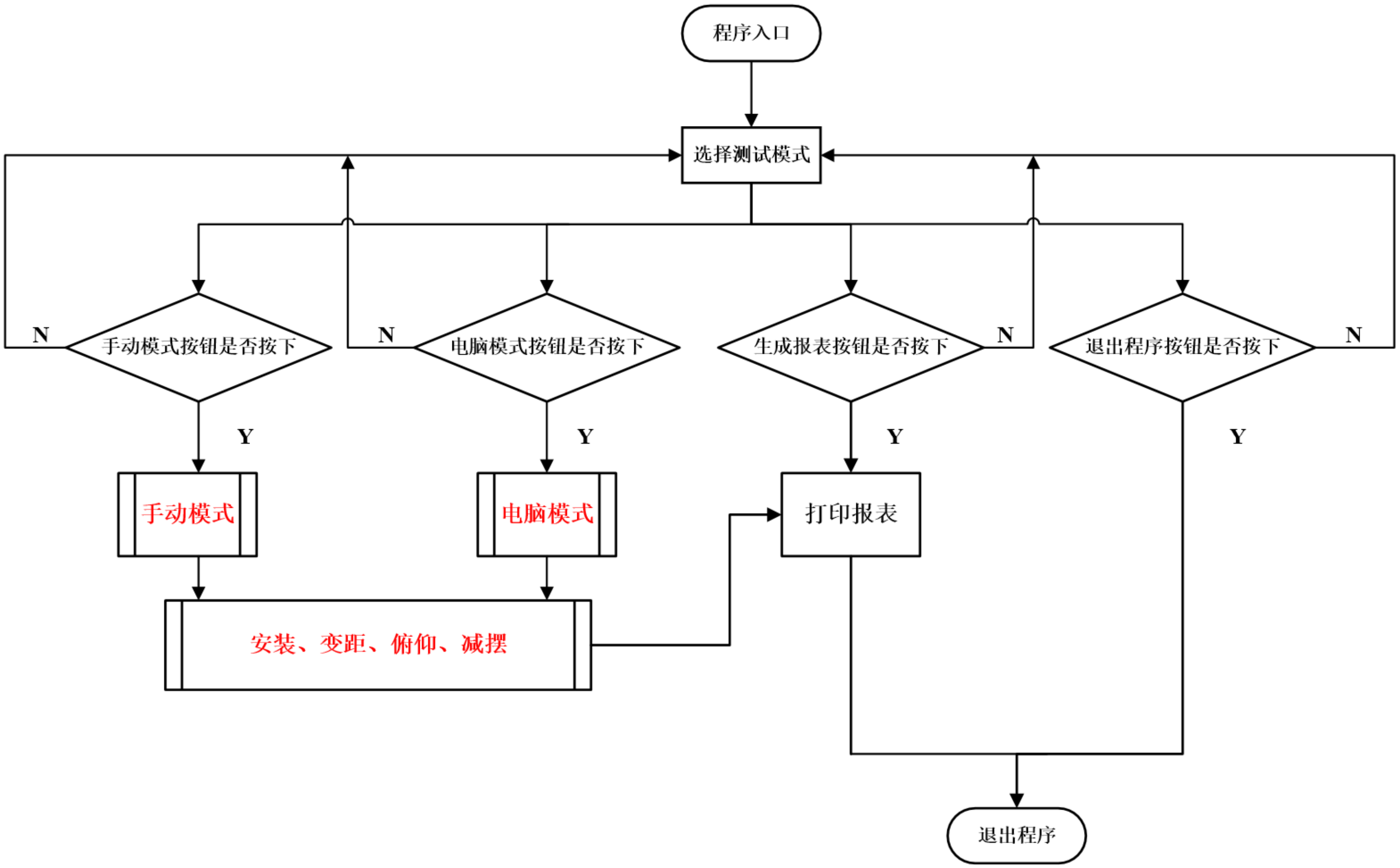
选择在 Microsoft公司的Visual Studio 2012设计平台上，以C++为设计语言，开发基于MFC类库的对话框程序。

通过向对话框添加控件，包括按钮、文本框，并插入背景图片，为每个按钮添加消息，定义并实现消息响应函数。通过调用控件成员函数，在程序中加载动态态链接库包括运动控制卡、CAN接口卡的Dll，调用里面丰富的库函数实现通讯功能、运动控制功能等。

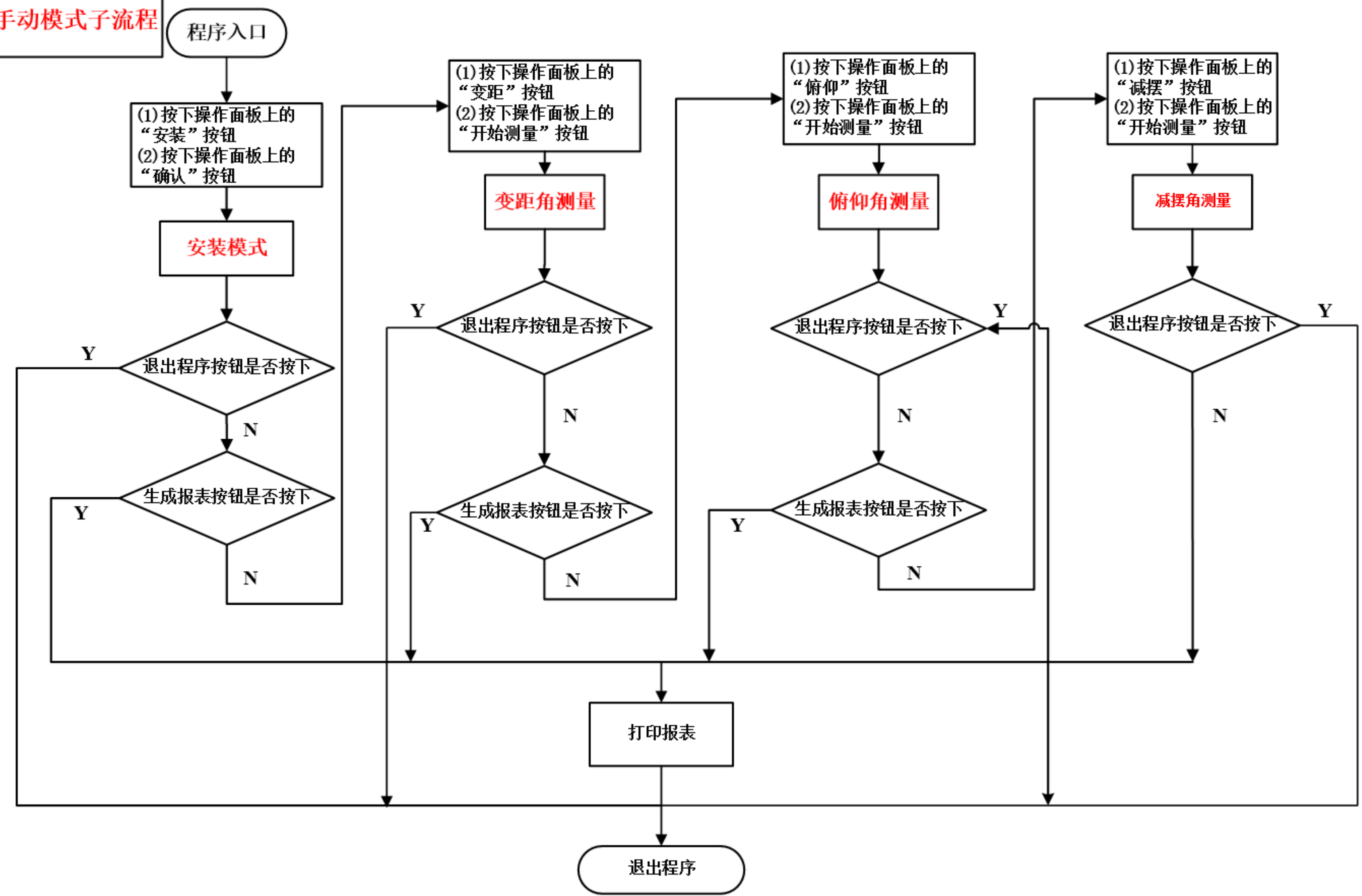
图 1-42 测试系统主界面功能区设计

图 1-43 安装模式界面功能区设计

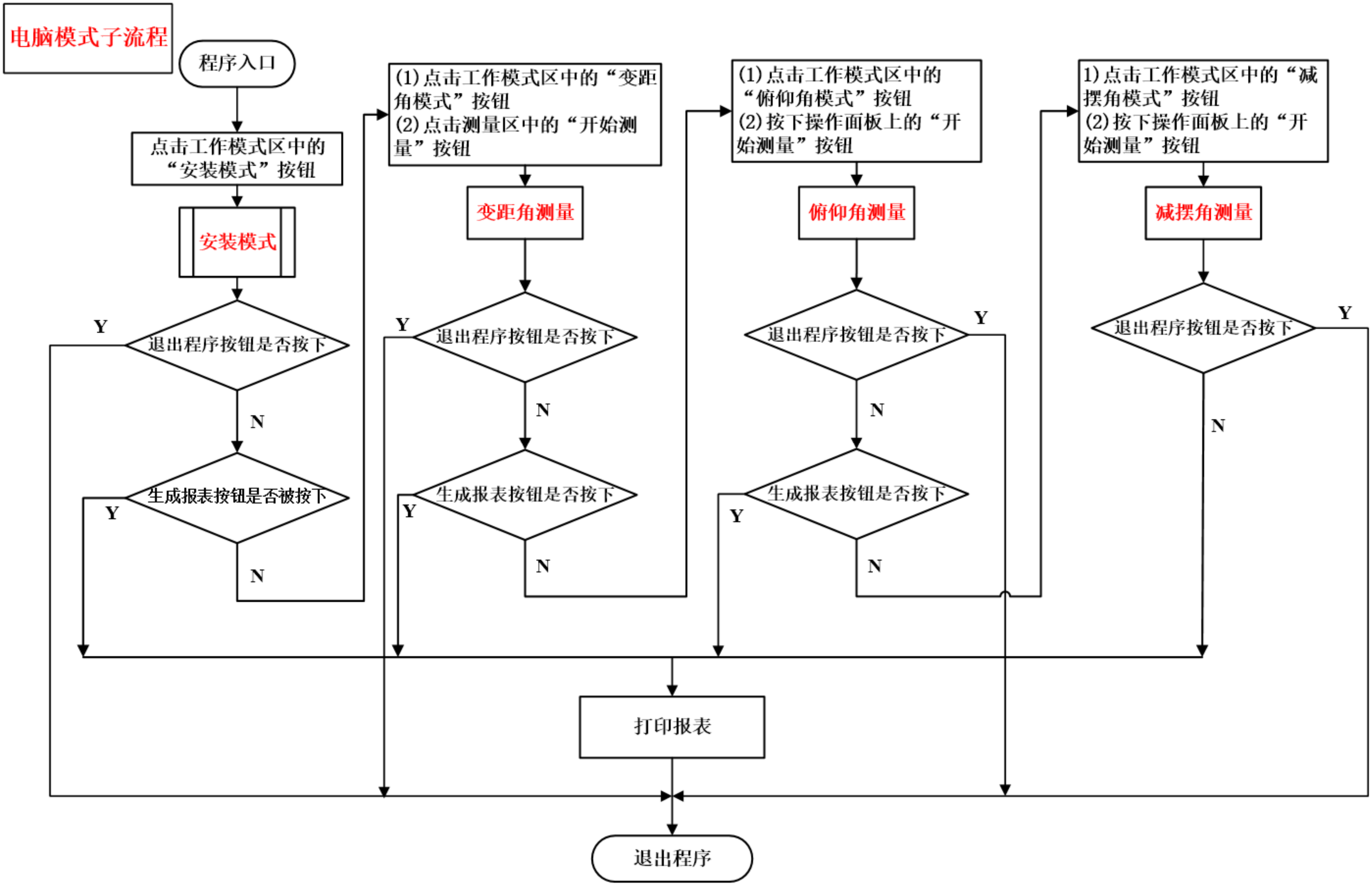
控制系统设计-结构设计


程序入口
选择测试模式
手动模式按钮是否按下
电脑模式按钮是否按下
生成报表按钮是否按下
退出程序按钮是否按下
N
N
N
N
Y
Y
Y
Y
手动模式
电脑模式
打印报表
安装、变距、俯仰、减摆
退出程序

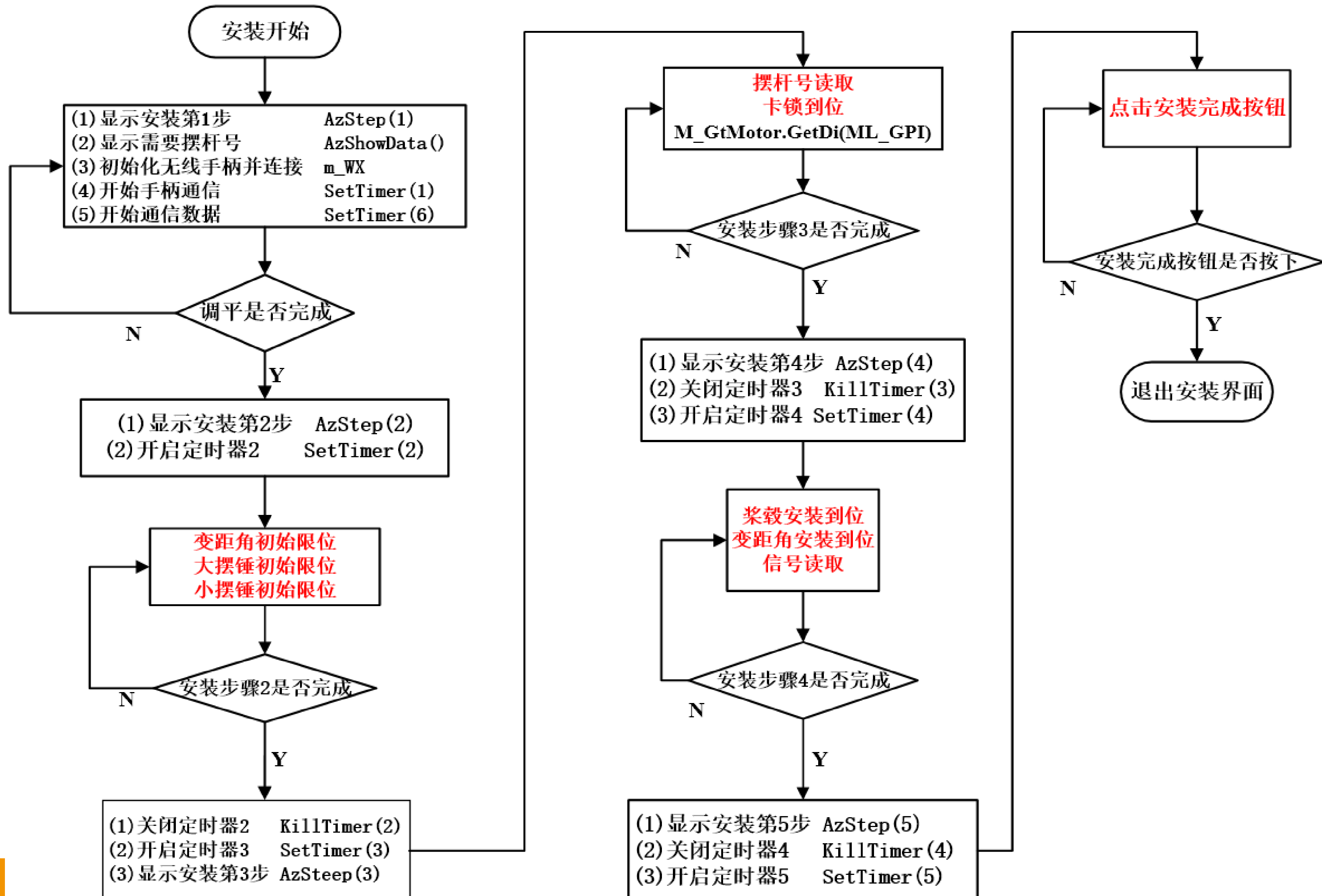
手动模式子流程


程序入口
(1)按下操作面板上的“安装”按钮
(2)按下操作面板上的“确认”按钮
安装模式
退出程序按钮是否按下
Y
N
生成报表按钮是否按下
Y
N
(1)按下操作面板上的“变距”按钮
(2)按下操作面板上的“开始测量”按钮
变距角测量
退出程序按钮是否按下
Y
N
生成报表按钮是否按下
Y
N
(1)按下操作面板上的“俯仰”按钮
(2)按下操作面板上的“开始测量”按钮
俯仰角测量
退出程序按钮是否按下
Y
N
生成报表按钮是否按下
Y
N
(1)按下操作面板上的“减摆”按钮
(2)按下操作面板上的“开始测量”按钮
减摆角测量
退出程序按钮是否按下
Y
N
打印报表
退出程序

控制系统设计-结构设计


电脑模式子流程
程序入口
点击工作模式区中的“安装模式”按钮
安装模式
退出程序按钮是否按下
Y
N
生成报表按钮是否被按下
Y
N
(1)点击工作模式区中的“变距角模式”按钮
(2)点击测量区中的“开始测量”按钮
变距角测量
退出程序按钮是否按下
Y
N
生成报表按钮是否按下
Y
N
(1)点击工作模式区中的“俯仰角模式”按钮
(2)按下操作面板上的“开始测量”按钮
俯仰角测量
退出程序按钮是否按下
Y
N
生成报表按钮是否按下
Y
N
1)点击工作模式区中的“减摆角模式”按钮
(2)按下操作面板上的“开始测量”按钮
减摆角测量
退出程序按钮是否按下
Y
N
打印报表
退出程序

控制系统设计-结构设计


安装开始
(1)显示安装第1步 AzStep(1)
(2)显示需要摆杆号 AzShowData()
(3)初始化无线手柄并连接 m_WX
(4)开始手柄通信 SetTimer(1)
(5)开始通信数据 SetTimer(6)
调平是否完成
N
Y
(1)显示安装第2步 AzStep(2)
(2)开启定时器2 SetTimer(2)
变距角初始限位
大摆锤初始限位
小摆锤初始限位
安装步骤2是否完成
N
Y
(1)关闭定时器2 KillTimer(2)
(2)开启定时器3 SetTimer(3)
(3)显示安装第3步 AzSteep(3)
摆杆号读取
卡锁到位
M_GtMotor.GetDi(ML_GPI)
安装步骤3是否完成
N
Y
(1)显示安装第4步 AzStep(4)
(2)关闭定时器3 KillTimer(3)
(3)开启定时器4 SetTimer(4)
桨毂安装到位
变距角安装到位
信号读取
安装步骤4是否完成
N
Y
(1)显示安装第5步 AzStep(5)
(2)关闭定时器4 KillTimer(4)
(3)开启定时器5 SetTimer(5)
点击安装完成按钮
安装完成按钮是否按下
N
Y
退出安装界面

控制系统设计-运动控制模块

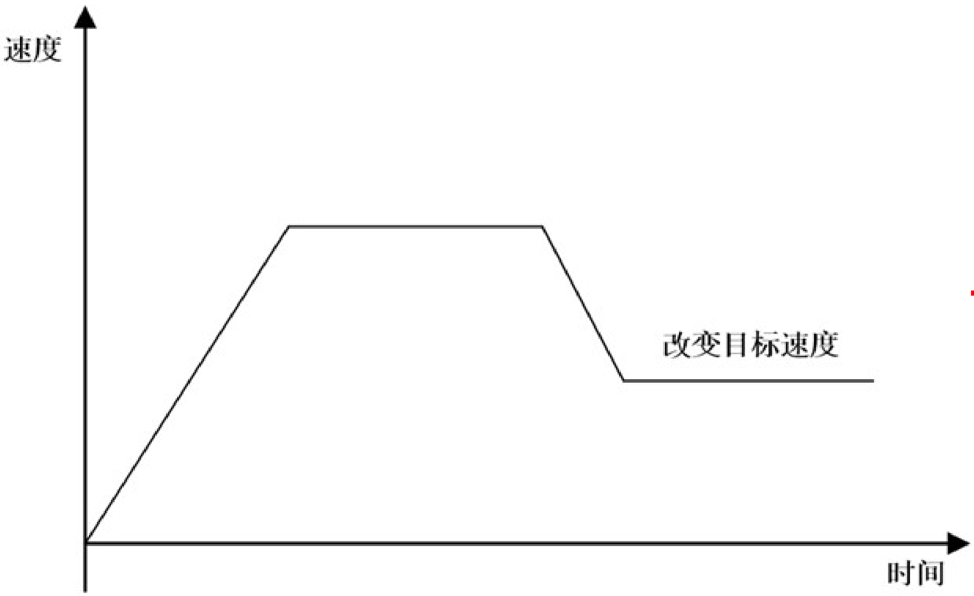


图 4-15 Jog 模式速度曲线

设置**目标速度**、**加速度**、**减速度**、**平滑系数**等运动参数。调GT_Update指令启动Jog运动

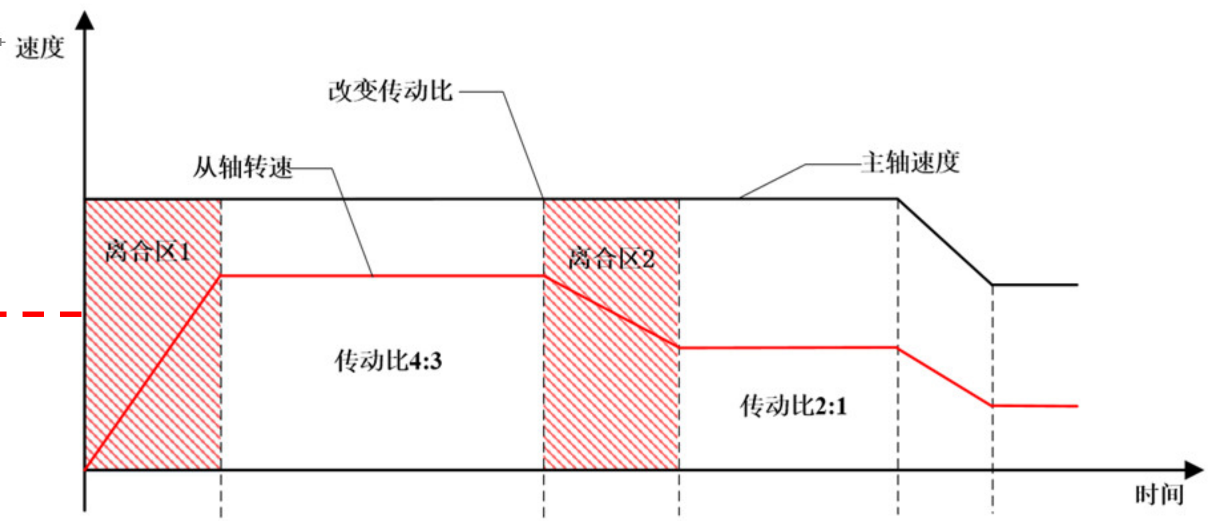


图 4-16 电子齿轮模式速度曲线

设置**主从轴**、**传动比**。可以设置离合区，实现平滑变速，调用GT_Update

控制系统设计-通讯模块

1、打开串口　通过PortOpen属性值来设置串口的状态
2、初始化串口　通过CommPort和Settings设置串口的通信参数
3、读写串口　get_Input和 set_Output
4、关闭串口　将PortOpen属性值设为False来关闭串口

串口通讯

陀螺仪
编码器

上位机

倾角仪

CAN通讯

1、打开设备　2、初始化某一路CAN　3、启动某一路
4、读取数据帧

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Thank you!