Design of Simulated Magnetic Gun

Jian Huang*
XiJing University, Xi'an City, Shaanxi Province, China 710123
*Corresponding author e-mail: huangjian@xijing.edu.cn

Abstract. STM32F103 single-chip microcomputer is used as the control unit of the simulated electromagnetic squint. The single-chip microcomputer is used to control the function of launching shell and steering gear angle, and the steering gear is used to control the launching angle and direction of the electromagnetic squint. In the design of electromagnetic gun, coaxial coil gun is used as the main part, and two batteries are used as the energy supply device. Then the electromagnetic relay connected with the single-chip microcontroller controls the cycle charging. Firstly, 12V DC power is input into the circuit by the DC stabilized voltage power supply. After the current enters into the circuit, it is divided into two branches. One branch flows through the boosting circuit of electromagnetic relay to charge the thyristor capacitor. With the switch off, the instantaneous discharge of the capacitor generates an inverter magnetic field in the coil, which pushes the metal projectile out at a high speed. What the electromagnetic relay does is to boost the voltage. What the thyristor capacitor needs is high voltage current charging. Another branch supplies 5V DC power to the steering gear through the step-down electromagnetic relay to support the rotation of the steering gear. The system obtains the target position through openmv, and STM32 uses PWM wave to control the rotation angle and direction of the steering gear.

Keywords: Electromagnetic Squint, STM32F103 Single Chip, Openmv, Laser Ranging Module

1. Theory and Analysis

1.1 Principle Discussion
The launch principle of this design is out of production and the launch principle of electromagnetic coil gun. First of all, the magnetic field is formed by the circular coil passing through the current. The direction of the magnetic field at the center of the coil can be regarded as a straight line passing through the center. The direction is determined by the right-hand rule of ampere. Each turn of coil will produce a small magnetic field in the same direction when the current passes through, so it is in the same direction, so the magnetic field strength in the coil is large, and the magnetic field emitted by each turn of coil outside the coil affects each other and the direction divergence is not the same, so the magnetic field produced will not affect the strength of the internal magnetic field. When the projectile in the coil adapts to the magnetic field, it suddenly changes the current direction, which changes the direction of the magnetic field, and the force will also change, resulting in a great change in the
potential difference, thus generating a strong ampere force to push the projectile to move to complete the launch [1-5].

1.2 Basic Parameters
Based on the foundation of electromagnetic coil gun, the realization of gun barrel needs to consider the safety factor, so the energy of launching is limited, so the realization process also has a change plan, raising the muzzle direction to make the launching process become a calculable curve will be much safer. So start to calculate the curve as shown in the figure below.

DC regulated power supply: input 12V, output 5V. Transformer: turns 30. Transmitting coil: diameter 20 mm, 400 turns. Silicon controlled bt151; the shell is a steel ball with a diameter of 1cm; The barrel is a 1.5cm diameter plastic tube.

Figure 1. Parabolic motion
Horizontal coordinate, vertical coordinate, projectile exit height, elevation angle (included with horizontal angle), projectile mass, initial velocity and air resistance coefficient.

Horizontal direction

\[ F_x = -kv_x = m\frac{dv_x}{dt} \]  
\[ v_x = v_{x0} e^{-kt/m} \]  
\[ x = \frac{mv_{x0}}{k} \left(1 - e^{-kt/m}\right) \]

Vertical direction

\[ F_y = -mg - kv_y = m\frac{dv_y}{dt} \]  
\[ v_y = \left(v_{y0} + \frac{gm}{k}\right) \exp(-kt/m) - \frac{gm}{k} \]  
\[ y = -\left(v_{y0} + \frac{gm}{k}\right) \frac{m}{k} \exp(-kt/m) - \frac{gm}{k} t + h + \left(v_{y0} + \frac{gm}{k}\right) \frac{m}{k} \]
For a given horizontal distance of the target, the projectile is launched at a fixed and high initial velocity scale, and the target can be hit accurately by choosing a suitable launching angle. This is the same as the aiming principle of the actual artillery, that is to say, it is to fix the initial velocity of the artillery shell and change the firing angle [6-7].

The analytic expression of its specific elevation and horizontal distance \( x \) is more complex, so we can let the single chip microcomputer carry out numerical calculation:

Elevation try from a smaller value

\[
\begin{align*}
\nu_{x_0} &= \nu_0 \cos \theta \\
\nu_{y_0} &= \nu_0 \sin \theta
\end{align*}
\]

Time required

\[
t = -\frac{m}{k} \ln \left(1 - \frac{kx}{mv_{x_0}}\right)
\]

\[
y = -\left(\nu_{y_0} + \frac{gm}{k}\right)\frac{m}{k} \exp\left(-\frac{kt}{m}\right) - \frac{gm}{k} t + h + \left(\nu_{y_0} + \frac{gm}{k}\right)\frac{m}{k}
\]

When the vertical height is very close to zero, it means that the projectile can hit the target accurately. If the vertical height at this time is not close to zero, increase the elevation angle and recalculate until it is close.

1.3 Energy Analysis

Based on the calculation of and curve and angle, the value of energy required for emission can be roughly obtained. However, for the accurate quantitative output of energy generated by electromagnetic field, the calculation of energy is also required, as follows.

For a single capacitor discharge, the following equation can be used:

\[
E_k = \frac{1}{2}mv^2 = 0.54J
\]

The electric energy kinetic energy conversion efficiency of small electromagnetic gun is usually maintained at about 10%. Here, we need to calculate the energy stored in the capacitance by 10%

\[
E_c = 5.4J
\]

The voltage required for 470uf energy storage capacitor is based on:

\[
E_c = \frac{1}{2}CU^2 = \frac{1}{2} \times 470 \times 10^{-6} \times 150^2 = 5.4J
\]

2. Working Principle

Firstly, the regulated DC is output by the regulated DC power \( R \), and then the regulated DC is input into the main circuit by the induction generator coil. The 12V DC regulated current forms a closed circuit with the thyristor 1, the boost electromagnetic relay 1, and the capacitor C. In this process,
capacitor C will boost 12V regulated DC to 450V high voltage current through boost electromagnetic relay to store energy for itself, and this circuit will be closed before capacitor C is charged. This process will be monitored and controlled by the control unit STM32F103. As the 450V high voltage current of capacitor C is not easy to monitor, the calculation and detection will be completed by the timing program built in STM2 chip. At this time, the thyristor 1 is in the closed state and the thyristor is in the open state. This process will continue until the capacitor C is full. After that, the control unit STM32F103 understands the capacitance through the data to fill up, and controls the opening of thyristor 1. At this time, the capacitance C, thyristor, step-down electromagnetic relay 2, diode 1 and inductance coil L form a closed circuit. Because the control unit causes the thyristor to close, the circuit is closed, but in fact, the current passing rate of inductance L is very limited, and capacitance C starts to discharge. At the same time, the 450V high voltage and current are released to form a path for L. The coil L quickly passes through the 450V high voltage and current to generate a strong instantaneous magnetic field in the design theory, and the magnetic field pushes the metal projectile to launch at a very high speed. Before this process, the other branch of the thyristor completes the step-down, and the 12V DC output 5V low-voltage current through the step-down to steadily supply energy to the steering gear. The steering and orientation of the steering gear are adjusted before the discharge, and the results are fed back to STM32F103 single chip microcomputer. The chip controls the discharge of the capacitance to complete the second step, and finally hits the target to achieve the experimental goal [8-10].

3. Test
Test method: determined by the design parameters, after automatically identifying the red target data and uploading it to the computer, adjust the angle of the steering gear to launch according to the data, and the continuous launch results are as follows:

![Figure 2. Shooting accuracy test results](image)

Result analysis: the root mean square of the error is in the longitudinal direction. The reason is that the gun barrel will shake when firing, so that the elevation angle of the gun barrel will change to some extent, which changes the accurate result of calculation.

4. Summary
This system uses STM32F103 single-chip microcomputer as the control unit. In the process of writing this paper, we have a deeper understanding of the electromagnetic gun technology. Openmv, a single-chip microcomputer control with excellent image processing function, is used to process the relevant image data, and capacitance, electromagnetic relay, steering gear, etc. are used to complete the hardware design and assembly.

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