Design and Development of the Flammability Tester

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Abstract. Among the international toy safety standards and national toy safety standards, the types of toys which need to be tested for flammability include: toys to be worn on the head, toy disguise costumes, toys intended to be entered by children, soft filled toys, and different types of toys have different flammability test methods. Based on the different test requirements, combined with PLC control technology and the working principle of high performance step-in motor, a multi-function flammability tester of toys is designed and developed. The function design, structure design and control principle of the flammability tester are discussed. It is pointed out that the use of this tester can not only solve the difficult problems in the test work of toys, but also greatly improve the quality and efficiency of toy safety test, and improve the automation level of the test work.

1. Introduction

Import and export toys need to go through a series of corresponding test, and flammability test is one of the important links. The international toy safety standards ISO 8124-2 has the most complex content about flammability test, involving five categories: toys to be worn on the head, toy disguise costumes, toys intended to be entered by children, soft filled toys, and different types of toys have different flammability test methods. Based on the different test requirements, combined with PLC control technology and the working principle of high performance step-in motor, a multi-function flammability tester of toys is designed and developed. The function design, structure design and control principle of the flammability tester are discussed. It is pointed out that the use of this tester can not only solve the difficult problems in the test work of toys, but also greatly improve the quality and efficiency of toy safety test, and improve the automation level of the test work.

In the test, first the toy is fixed by hanging type. Secondly, measure the size of the toy. Thirdly, according to the type of the toy, the ignition position is determined, and adjusted the position between the flame burner and the toy. Then the burned size and burned time of the toy are measured. Finally, the flammability rate is calculated and the results are output. At present, there is no automatic toy flammability test equipment at home and abroad, and the current test is all done by artificial way and leading to the inaccurate results.

With the development of the computer control technology, PLC (programmable logic controller) now is the wider application of the control device. It has many advantages as modular structure, high-speed processing speed, accurate computing, variety of control and so on[1]. In view of the above problems, an automatic flammability tester which used advanced PLC control technology was developed. The equipment meets the requirements of safety standards EN71-2, GB6675.3 and ISO 8124-2 for the flammability test of toys. It solves the difficult problems in the practical test work and improves the quality and efficiency of the test for Import and export toys.
2. Structure Design
The flammability tester designs as cabinet form configuration and model structure. It makes up of six parts which are test device, ignition device, control system, Human Computer Interface, output system, communication interface, as shown in Figure 1.

The designed Flammability Tester is a stainless steel metal cabinet structure, which is divided into upper and lower parts. The upper cabinet is a stainless steel combustion chamber and a glass observation window, which is equipped with test device (include a marking thread mechanism, a tested object positioning mechanism, a testing mechanism, a burner positioning mechanism, a burner mechanism), ignition device, HCI (Human Computer Interface). The right side of the front of the upper cabinet is the operation panel, which is equipped with touch screen, micro printer, gas regulating valve, change-over switch, exhaust fan switch and main power switch. The panel is also equipped with an Ethernet interface.

The lower cabinet is composed of control system and gas room, which are isolated from each other. The gas room is used to place butane gas tank, and the control system is used to install electrical equipment and components such as main controller, I/O device, drivers, DC power supply, main power switch and wiring terminal of the tester.

![Figure 1. Tester structure](image)

3. Mechanism Design
The mechanical mechanism of the tester includes "test object positioning mechanism" for positioning the tested object, "test mechanism" for testing the length, extension length and burning length of the object, "burner positioning mechanism" for positioning the flame burner, "burner mechanism" and "marking thread mechanism" for plane positioning of the flame burner and positioning of the test standard line; These mechanisms are composed of different lead screw, mechanical slider, guide rail, photoelectric limit switch and timing switch. At the same time, temperature and humidity sensors are set to complete the measurement of the test environment. The design of the distribution distance between
the mechanisms meets the test requirements of the five types of toys in the standard, and completes different functions in the test process.

3.1. **Test object positioning mechanism**

The test object mechanism is used to fix and locate the object to be tested. The positioning of the object to be tested is mainly realized by the reference point positioning mechanism. The mechanism is shown in Figure 2. Because there are many types and sizes of toys tested, the benchmark of toys is not necessarily the end point of toys, and testers need to determine the effective benchmark position according to the type of toys. During the test, the operation of the test object mechanism is controlled, and the slider on the reference point positioning mechanism moves on the guide rail, and the position of the reference point is determined by the contact pin on the slider. The slider and guide rail are designed to increase the positioning range. The pin can move freely horizontally on the slider. The positioning range of this mechanism is 0-300 mm.

In order to fix and position the tested object, the tested object mechanism designs two fixed supports, as shown in Figure 2. The fixing bracket 2 is used for fixing toys, such as to be worn on the head, toy disguise costumes, toys intended to be entered by children. The fixing bracket 1 is used to fix the other two kinds of toys, because this kind of toys generally adopt the hanging type of steel needle. The porous design on the bracket 1 is to increase the fixed position of the tested object and make the tested object fully and stably fixed. The guide rail structure between the fixed bracket 1 and the mechanism is designed to increase the positioning range, which can be positioned according to the size of different toys. The fixed bracket 2 is a movable structure, which can be taken down or buckled on the guide rail of the fixed bracket 1.

![Figure 2. Test object positioning mechanism](image1)

![Figure 3. Test mechanism](image2)

3.2. **Test mechanism**

The design of the test mechanism is shown in Figure 3. The test range is 0-580mm, which is used to measure the effective length and burnt length of the object to be tested. This mechanism needs to cooperate with the marking mechanism to complete the test. When the test is started, the marking mechanism is aligned with the bottom end of the object to be tested through the test mechanism, which is the zero point. Then the test mechanism drives the marking mechanism to rise to the top end of the object to be tested, and the distance of the test mechanism is the effective length of the object to be tested. After the test, the distance from the ignition position to the top end of the object is the burned length. Therefore, the length and burned length of the tested object are automatically recorded by the
two mechanism testers, and the burned speed of the tested object can be obtained by combining the burned time determined by the timing device.

3.3. Burner positioning mechanism and burner mechanism
The design of burner positioning mechanism and burner positioning mechanism are shown in Figure 4. The latter is installed on the burner mechanism. Considering the different sizes and shapes of the tested toys, it is necessary to find a suitable ignition position, so the burner is installed on a rotatable plane. The burner mechanism is designed to rotate within a certain radius with a rotation range of 0-180° and a rotation radius of 600mm, while the positioning range of the burner positioning mechanism is 0-600mm. The two mechanisms cooperate with the positioning mechanism of the test object to realize the three-dimensional positioning of the burner based on the positioning of the reference point. When the burner is ignited, the burner positioning mechanism drives the burner to move to the ignition position, and the timing device starts timing.

3.4. Marking thread mechanism
The design of the marking mechanism is shown in Figure 5. The marking mechanism is used to fix the standard thread cotton thread during the test. The standard thread is not only used as the length ruler of the object to be tested, but also as the ruler for controlling the burning time. The timing device on the mechanism is designed as the heavy hammer type. When the cotton thread is burnt out, the heavy hammer falls, and the timing device stops timing.

Figure 4. burner positioning mechanism and burner mechanism
4. Control System

4.1. Work principle

The control system of the tester consists of S7-200 series PLC controller, step-in motor, drive control device and conversion switch. Among them, PLC adopts one CPU224XP of Siemens S7-200 series, two extended position control modules EM253 and one DC 24V power supply. After the tested toy is fixed to the "test object mechanism", select the toy type through the operation interface of the touch screen, and the tester determines the test reference point according to the type of the tested toy. According to the determined reference point position and human-computer interaction information, the tester processes these information and outputs pulse control signals by PLC in the control system. The driver receives these signals and controls the operation of step-in motor after amplification and matching processing. As an actuator, the step-in motor drives the load (i.e. each "mechanism") to run automatically. PLC can automatically record the output pulse signal according to the operation state of each mechanism, process the signal and accurately calculate the operation process value of each mechanism. For different mechanisms, through different mathematical models, the test parameters such as the measured toy length, burned length and flame positioning height can be obtained respectively, and the accurate burned time can be obtained according to the timing switch signal. At the same time, the required measurement results are calculated automatically. These results can be output in different forms through man-machine interface, printer and network. The tester completes a closed-loop test and control process, as shown in Figure 6. The tester realizes a four-axis linkage motion control.

A limit switch is set for each test mechanism in the instrument, which not only ensures the test range, but also makes the test process safe and reliable. After using the change-over switch, a driver can control the operation of "burner" and "marking thread".
4.2. High speed pulse signal control principle

PLC CPU224XP controller body is integrated with 2-way high-speed pulse output signals Q0.0 and Q0.1, which output high-speed pulse signals with pulse frequency of 20-100kHz, which can be used to control step-in motor. In the tester, the two high-speed pulse output signals are used to control three step-in motors: "burner positioning mechanism", "burner mechanism" and "marking thread mechanism", in which "burner mechanism" and "marking thread mechanism" share one driver and one PLC control signal through the change-over switch.

In the "burner positioning mechanism" control system, the high-speed pulse signal Q0.0 of PLC is output to the "P" end of the driver, which directly controls the movement of the step-in motor after amplification and matching processing by the driver. The "D" end of the driver is the direction signal end, and the limit switch signal on the travel limit is used as the direction signal of the step-in motor to make the step-in motor move within the effective range. The "M" end of the driver is the common end of the signal. The drive is powered by a 48V DC power supply[3].

In the control system of "burner mechanism" and "marking thread mechanism", the driver controls the step-in motor according to the output of high-speed pulse signal. The control principle is the same as that of "burner positioning mechanism". The "D" end of the driver is the direction signal end, and the limit switch signal on the travel limit is used as the direction signal of the step-in motor to make the step-in motor move within the effective range. The "M" end of the driver is the common end of the signal. The drive is powered by a 48V DC power supply. The driver is selected by the change-over switch to control the movement of one of the two motors.
5. Conclusions
The flammability tester adopts Siemens S7-200 series CPU224XP PLC controller and SH-20806N-DA step-in motor drivers to ensure the stable operation, fast response and high precision of the tester. The use of this tester can not only reduce test error, but also greatly improve the efficiency of the toys test, improve the accuracy of test results, and improve the automation level of test work. The tester has a broad application prospect in toy safety test.

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