Design and Application of Lottery Box Number Inkjet System for Packaging Based on PLC Technology—A Study on Thermal Tickets of China Sports Lottery

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Abstract: Thermal tickets for sports lottery feature a single specification. After roll-to-roll printing, they proceed to subsequent processing and packaging procedures. In line with production capacity matching, the post-printing process is a fully automated assembly line integrated with 4 slitting machines, 1 plastic sealing machine, 1 cartoning machine, an inkjet system, and other associated equipment. Recently, traceable serial numbers have been added to the surface of thermal tickets, roll numbers to small rolls post-slitting, and box numbers to the final packaging boxes. Given that the printing machine and slitting machines operate relatively independently, a one-to-one correspondence between roll numbers and ticket numbers can be easily achieved. However, in the post-printing process, 4 slitting machines are connected to a single cartoning line, which creates challenges in matching the slit small rolls with the cartoning inkjet system. Through research on the box number inkjet system developed by Japan's KGK Company, it was identified that it's I/O interface [1] possesses a multi-channel information selection function for inkjetting. Combined with the existing belt conveyor system of the slitting machines, PLC programming can be implemented to control the cartoning inkjet system—enabling the system to call the corresponding box number for inkjet printing when small rolls are conveyed from a specific slitting machine. In other words, the 4 slitting machines can independently produce products with different number segments or even products designated for 4 different provinces, all of which can be integrated with the subsequent plastic sealing machine, cartoning machine, and inkjet system [2] to form a fully automated continuous production process.

Keywords: PLC; Lottery; Packaging; Inkjetting; Thermal Ticket; Full Automation; Assembly Line

1. Introduction

Currently, lottery tickets available in Chinese market are categorized into two major systems: welfare lottery and sports lottery. Each system is further divided into two types based on form: scratch-and-win tickets (referred to as "instant tickets") and computer-printed tickets (referred to as "thermal tickets"). Instant tickets are printed on white cardboard via roll-to-roll technology, involving complex printing processes and diverse ticket surface specifications—making full automation of their post-printing procedures difficult to achieve. The inkjet process is a critical component of lottery printing, and variable data inkjetting [3] for instant tickets, in particular, serves as the core process for

instant ticket printing.

In contrast, thermal tickets are printed on thermal paper using roll-to-roll technology and have a uniform surface specification. For China sports lottery tickets (used as the research subject hereafter), only one specification is adopted: 101.6mm × 79mm. This uniformity facilitates the full automation of post-printing processing. Similarly, the inkjet process runs through the entire process of thermal ticket printing and post-printing—a key point that ensures inkjet technology is integrated into both core production stages. Initially, thermal tickets lacked serial numbers, as their value is generated only after the numbers selected by purchasers are printed via computer—meaning no inkjet process was included in the printing stage. To meet the certification requirements of the ISO9000 quality management system, enhance the China Sports Lottery Center's control over lottery tickets released to the market, and ensure the traceability and authenticity of sold tickets, serial numbers were subsequently added to the surface of thermal tickets.

In alignment with production capacity requirements, China Sports Lottery Printing Technology Co., Ltd. has introduced 3 independent roll-to-roll printing production lines and 1 fully automated post-printing packaging line—comprising 4 slitting machines, 1 plastic sealing machine, 1 cartoning machine, and other equipment [4]. After serial numbers are inkjet-printed on ticket surfaces, a correlation exists between ticket numbers and box numbers in the packaging line. To prevent number mismatches, the enterprise previously adopted manual operations: workers manually sorted slit small rolls (with roll numbers inkjet-printed on outer lining paper), counted 20 rolls, and placed them on the plastic sealing line for packaging.

Against this backdrop, a set of PLC control systems was designed to achieve linked control between slitting machines and the cartoning inkjet system [5]. This system ensures that when each small roll of lottery tickets enters the cartoning inkjet system, the source slitting machine is automatically identified, and the corresponding box number is retrieved for inkjet printing. Beyond improving production efficiency, this system enhances the traceability of lottery tickets and provides technical support for subsequent automated production [6].

2. Design of Thermal Ticket Packaging Inkjet System

2.1 Overview of Thermal Ticket Production Process

As a printing medium for lottery sales terminals, thermal tickets function as follows: when a purchaser buys a ticket on-site, the betting results are printed on the thermal coating of the ticket, and the betting information is stored in the computer system of the sales terminal. During the lottery drawing, the betting information is verified against winning information; if a match is confirmed in accordance with game rules, the purchaser is eligible for a prize.

Due to the special application requirements of thermal tickets, production relies on dedicated "three-proof" thermal paper with a grammage of 75 GSM, and strict standards are imposed on printing quality—especially to ensure the readability of each ticket. The printing of thermal tickets primarily involves six-color UV offset printing on the non-coated side to produce thematic color patterns, lottery instruction text, readability marks, and exclusive logos of China Sports Lottery, as well as anti-counterfeiting stripes printed on the coated side. This process is completed by a narrow-web bill rotary printing machine through roll-to-roll printing.

The second stage of thermal ticket production, collectively referred to as the post-printing process, involves: slitting large rolls into small rolls and rewinding them using a fully automated small-roll slitting machine; followed by plastic sealing, cartoning, box sealing, inkjetting, and

packaging of the products.

In summary, the thermal ticket production process consists of four key stages: printing, slitting, packaging, and inkjetting.

The detailed production workflow is as Figure 1:

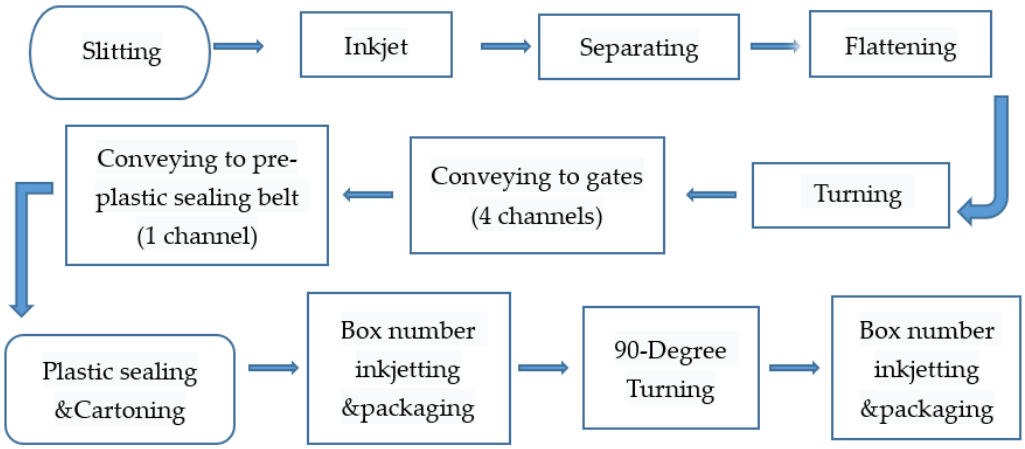


Figure 1: Flowchart of Post-Printing Packaging and Inkjetting for Small Rolls.

2.2 Correlation of Thermal Ticket Numbers

The specification of a single thermal ticket is 101.6mm × 79mm. Each printing machine has a width capable of producing 5 columns simultaneously, with 5 piezoelectric nozzles used to print serial numbers on the 5 columns of ticket surfaces, respectively. This piezoelectric inkjet technology has been widely applied in the market, and the Ricoh GEN6 series is adopted in this study.

Each ticket is printed with a unique number, consisting of an order code, a box number, and a single-ticket serial number—totaling 14–16 characters (formatted as XXXXX999990000). The first 5–7 characters (XXXXX) represent the order code (in English), the subsequent 5 characters (99999) denote the box number, and the final 4 characters (0000) are the single-ticket serial number.

Each nozzle prints 500 consecutive serial numbers (ranging from 0000 to 0499), while the adjacent second nozzle prints the next 500 serial numbers (ranging from 0500 to 0999), and so on.

The specification of small rolls post-slitting is as follows: diameter = 78mm, height = 79mm. Each slitting rod is divided into 5 rolls, and the inkjet number on small rolls includes characters and a management number—totaling 12–14 characters (formatted as XXXXX9999900). The first 5–7 characters (XXXXX) are the order code (in English), the first 5 digits (99999) are the box number, and the last 2 digits (00) are the roll number. The roll numbers of one rod are consecutive, such as 20, 19, 18, 17, 16; 15, 14, 13, 12, 11; 10, 9, 8, 7, 6; or 5, 4, 3, 2, 1.

Every 20 small rolls (equivalent to 4 rods) are packed into one box, with the internal dimensions of the box being 390mm × 156mm × 158mm (i.e., 5 rolls in length, 2 rolls in width, and 2 rolls in height). The cartoning inkjet system prints the following content on the outer surface of the box: order code+ box number (e.g., XXXXX99999, XXXXX99998, XXXXX99997, etc.). Each roll of tickets must be packed into the carton corresponding to its ticket number.

As evident from the above, box number information is printed on both individual tickets and the outer surface of each roll. Thus, regardless of the transportation process, only the corresponding box number information can be printed during the cartoning inkjet system stage.

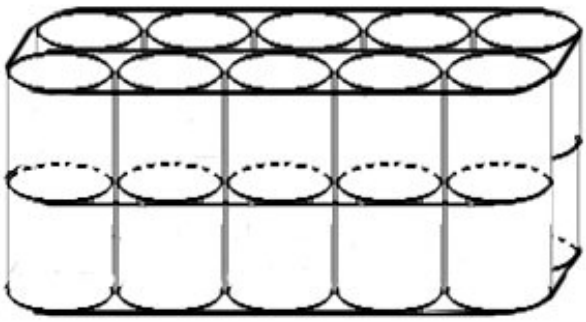


Figure 2: Schematic Diagram of Cartoned Products.

2.3 PLC Process Control Design

In the slitting process, 4 slitting machines continuously convey small rolls to the same conveyor line in front of the plastic sealing machine via 4 belt conveyor lines (marked as 1, 2, 3, and 4 in Figure 4). Since the 4 rods (20 rolls) continuously slit by each slitting machine share the same box number and must be packed into the same carton, it is necessary to control the 4 slitting conveyor lines. Specifically, the products delivered from each slitting conveyor line to the plastic sealing line must form a full box (i.e., 20 rolls). Only when the finished cartons (post-cartoning) reach the inkjet stage (at the two red elliptical positions in Figure 3) can the cartoning inkjet system accurately print the box number information.

To achieve this, the slitting output line is divided into two segments: the secondary conveyor line (adjacent to the output disk) and the primary conveyor line (adjacent to the slitting machine). Two photoelectric sensors (for counting) and two pneumatic gates are installed on the secondary conveyor line (see Figure 4). Based on the length of 20 small rolls, the distance between the two pneumatic gates is designed to be 1600mm, with PLC controlling the opening and closing of the gates.

The operational logic is as follows: After startup, if no small rolls are present on the secondary conveyor line, the right pneumatic gate lowers, the left pneumatic gate lifts, and the secondary conveyor line operates to convey small rolls to the right pneumatic gate. When the number of small rolls on the secondary conveyor line reaches 20, the left pneumatic gate lowers, and the secondary conveyor line stops operation—while the primary conveyor line continues to run, conveying small rolls to the left pneumatic gate. A photoelectric sensor is installed at the buffer belt in front of the plastic sealing machine (see Figure 4). If no small rolls are detected by this sensor for approximately 0.5 seconds, it indicates sufficient space at the buffer belt. At this point, the right pneumatic gate opens; after 20 rolls (counted by the sensor) are released, the right pneumatic gate closes. Subsequently, the left pneumatic gate opens, and after 20 rolls (counted by the photoelectric sensor) are fed in, the left pneumatic gate closes again. This ensures that exactly 20 consecutive small rolls are fed into the plastic sealing and cartoning system each time—with no excess or shortage.

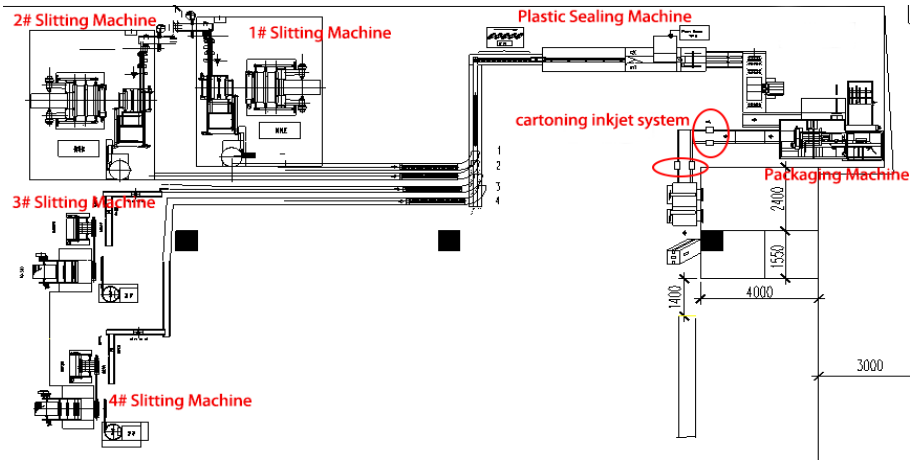


Figure 3: Schematic Diagram of Post-Printing Slitting and Cartoning Layout.

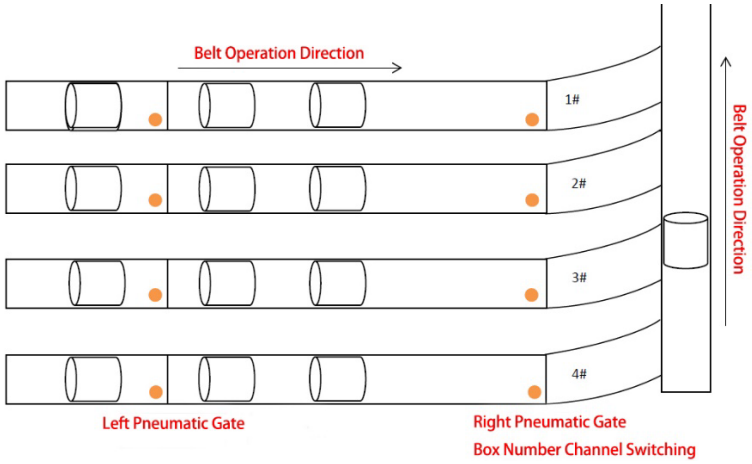


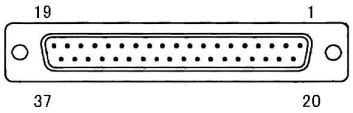
Figure 4: Schematic Diagram of Slitting Conveyor Line Control.

2.4 *Integration of PLC and Cartoning Inkjet System*

While conveying 20 small rolls (from each of the 4 slitting machines) as a single unit to the same belt in front of the plastic sealing machine ensures the accuracy of rolls in the same box, a key challenge remains: how to enable the cartoning inkjet system to print the correct box number information, thereby aligning box number inkjetting with the roll numbers and ticket numbers of products inside the box.

Currently, most inkjet systems can be equipped with I/O interfaces, which allow direct connection to external signal sources—enabling automatic control of the inkjet system via external signals without the need for additional computers or specialized devices. The objective of this study is to realize multi-product ink jetting with a single car toning inkjet system on the same production line: printing different information on the outer packaging boxes of 4 distinct products. A set of PLC systems is used to provide different information signals; the inkjet system automatically identifies and switches between signals. By connecting the I/O controllable ports of the inkjet system to the PLC signal terminals, the integrated application of automated packaging and inkjet systems for thermal tickets is achieved. This study takes the HQ8500 inkjet printer from Japan's KGK Company [8] as an example for system design.

I/O	Signal name	Signal content	Initial value	Pin no.	Circuit Config.
Input	Print sensor	Print command		2	b
Input	IN0	Message selection 1		3	a
Input	IN1	Message selection 2		21	a
Input	IN2	Message selection 4		4	a
Input	IN3	Message selection 8		22	a
Input	IN4	Message selection 16		5	a
Input	IN5	Message selection 32		23	a
Input	IN6	Message selection 64		6	a
Input	IN7	Message selection 128		24	a
Input	IN8	Allocation input signal by setting It shows the allocation signal.	Message selection STB	8	a
Input	IN9		Numbering reset	26	a
Input	IN10		Numbering update	9	a
Input	IN11		Numbering update prohibition	27	a
Input	IN12		Printing prohibition	10	a
Input	IN13		Calendar updated	28	a
Input	IN14		Calendar update prohibition	11	a
Input	IN15		unused	29	a
Output	OUT0	Allocation output signal by setting It is shown in the allocation possible signal。	unused	13	d
Output	OUT1		Ready (ready)	31	d
Output	OUT2		During printing	14	d
Output	OUT3		Ink LOW	32	d
Output	OUT4		Ink OUT	15	d
Output	OUT5		alarm	33	d
Output	OUT6		BUSY	16	d
Output	OUT7		unused	34	d
Output	+12V Power supply	Total output current 0.5A or less		18, 20, 25, 30, 36	
GND	GND	Common Ground		1, 7, 12, 17, 19, 35	
N.C.		Blanc		37	



This unit side connector is RDCD-37S-LNA (55) is [made by Hirose Electric].
Recommended connector for connection will be HDCB-37PF (05).

Figure 5: I/O Communication Definition of the HQ8500 Inkjet System.

As shown in Figure 5, one I/O communication board of the HQ8500 inkjet system supports 8 information channels. The 4 slitting conveyor lines × 2 box sides (2 nozzles) exactly match 8 information contents—meaning one I/O board can meet the inkjetting needs of 2 box sides, while an additional I/O board is required for inkjetting on the other 2 box sides. The following design description focuses on one I/O board.

The 4 channels of the slitting conveyor line correspond to the 4 slitting machines (marked as 1#, 2#, 3#, and 4#). First, Information 1, Information 2, Information 3, and Information 4 are configured on the cartoning inkjet system, corresponding to the 1#, 2#, 3#, and 4# slitting channels, respectively. Channels 1 and 16 of the inkjet system call Information 1; Channels 2 and 32 call Information 2; Channels 4 and 64 call Information 3; and Channels 8 and 128 call Information 4.

An identification sensor is installed at the front end of the cartoning inkjet system's nozzle. The PLC of the conveyor line controls the corresponding channel signals and connects to the inkjet system via the I/O interface. Before the packaging box reaches the nozzle, the corresponding channel signal is identified and transmitted to the cartoning inkjet system. Upon receiving the signal, the inkjet system retrieves the matching information number; after photoelectric induction, the inkjet system completes the printing of the corresponding content—fulfilling the requirement of channel-specific box number inkjetting on the production line.

Since one controller of the cartoning inkjet system controls 2 nozzles simultaneously, inkjetting is

performed on 2 sides of the box at the same time during printing. The correlation between the information numbers of Nozzle 1 and Nozzle 2 during information switching is shown in Table 1.

Table 1: Correlation Between Inkjet Printer Information Channels and Slitting Machines.

Conveyor Line	Corresponding Channel of Nozzle 1	Corresponding Channel of Nozzle 2	Inkjet Information
Slitting Channel 1#	1	16	Information 1
Slitting Channel 2#	2	32	Information 2
Slitting Channel 3#	4	64	Information 3
Slitting Channel 4#	8	126	Information 4

As previously noted, 20 rolls from each slitting channel are fed into the pre-plastic sealing channel as a single unit. Therefore, the closing of the right pneumatic gate (in Figure 4) is used as the input information for the PLC of this channel. After the output passes through an intermediate relay, it connects to the corresponding channel of the box number inkjet controller—calling the inkjet information of this channel and printing the box number information of 20 thermal ticket rolls on 2 sides of the box.

Since the information printed on the two opposite sides of the packaging box is identical (see Table 1), a single trigger signal is used for Information Channels 1 and 16, another for Channels 2 and 32, another for Channels 4 and 64, and the last for Channels 8 and 128. For detailed logical relationships, refer to Table 2.

Table 2: I/O Correlation Between Inkjet System and PLC.

Information Channel	Inkjet Controller Input PIN No.	PLC Output	Intermediate Relay
(1) 16	(3) 5	Y73	KA42
(2) 32	(21) 23	Y72	KA41
(4) 64	(4) 6	Y71	KA40
(8) 128	(22) 24	Y70	KA39
GND (COM)	1	ZP0	—
STB (Strobe Signal)	8	Y74	KA38

The PLC is intended to be activated at a low level; therefore, it is selected from the Delta DVP-ES2 series, adopting transistor (T) output—specifically, NPN open-collector output—and thus the DVP60ES200T model is chosen. To enhance operational convenience, the system is equipped with a Human-Machine Interface (HMI), which is used to display the status of the slitting machines, the operating conditions of the inkjet system, and alarm information. Operators can perform parameter setting, fault diagnosis, and system maintenance via the HMI [9].

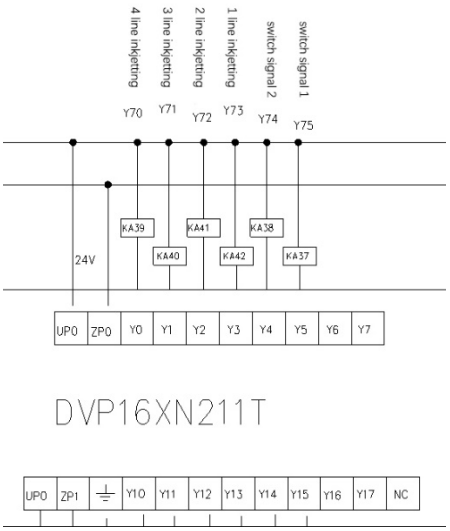


Figure 6: PLC Logic Diagram.

As indicated in Tables 2 and Figure 6, Pins 3 and 5 of the inkjet controllers are connected in parallel to the normally open terminal of Relay KA42; Pins 21 and 23 to the normally open terminal of Relay KA41; Pins 4 and 6 to the normally open terminal of Relay KA40; and Pins 22 and 24 to one terminal of Relay KA39. The other terminals of the four relays are connected in parallel to the normally open terminal of KA38, with the other terminal of KA38 connected to a low level. After inkjetting is completed, the PLC receives feedback signals from the inkjet system to confirm the success of inkjetting and transmits the results to the upper computer for monitoring [10].

3. Conclusion

Through an analysis of the traditional computer ticket slitting and packaging process, combined with the functional characteristics of the piezoelectric large-character inkjet system, quantitative control of product conveying was added to the existing automatic conveyor line. By fully utilizing the I/O interface of the inkjet system to connect with the signal source of the conveyor line, the original slitting and packaging production line was integrated with the cartoning inkjet system—expanding the entire post-printing processing line into a fully automated assembly line that integrates slitting, plastic sealing, automatic cartoning, box sealing, inkjetting, and packaging. This integrated line completes the processes of large-roll slitting, small-roll inkjetting, packaging, and box number inkjetting for thermal tickets, and successfully realizes production line customization: the 4 slitting machines can independently produce products with different number segments or even products for different provinces, while the inkjet system on the same production line accurately prints the corresponding box number information.

By using PLC to control the piezoelectric Drop-on-Demand (Piezo-DoD [11]) inkjet system, the automated linkage between slitting machines and the inkjet system is achieved—eliminating manual intervention and improving production efficiency. Meanwhile, the system enables real-time monitoring of the operating status of each link, ensuring the stability of the production process [12]. The inkjet system accurately records the source and inkjet information of each small roll of lottery tickets, guaranteeing the traceability of lottery tickets—this is of great significance for the China Sports Lottery Center's market issuance and quality control [13].

The system realizes full-process automation from slitting to cartoning, reducing manual operations and lowering labor costs. Additionally, it is equipped with automatic alarm and fault diagnosis functions, which improve equipment reliability [14]. The design of the lottery packaging inkjet system based on PLC technology also holds value in the field of confidentiality. Beyond its application in the post-printing processing of sports lottery tickets, this system can be promoted to the printing and packaging of other thermal tickets and valuable securities. In the future, with the continuous advancement of industrial automation, this PLC-integrated inkjet technology will play an important role in more fields.

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