Currency Identification Device for Global Markets "FGC Series" and "FGB Series"

OIWA, Takeshi* TANAKA, Nobuyuki* YAMANE, Takuya*

ABSTRACT

Fuji Electric has developed the "FGC Series" and "FGB Series" currency identification devices for global markets such as China and Association of Southeast Asian Nations (ASEAN) region. To speed up the commercialization of the devices according to the various kinds of size and design of currencies by modifying a portion of the components and software, we have implemented a common design, in which base components and configuration are standardized. Furthermore, we have met an identification performance to ensure reliability by equipping a coin handling device (coin mechanism) with a coin escrow function and new inspection algorithm that enhances the identification of material, as well as equipping a paper currency identification device (bill validator) with a line sensor and identification algorithm.

1. Introduction

Fuji Electric has manufactured coin handling devices (coin mechanisms) and paper currency identification devices (bill validators) as currency identification devices to be installed in vending machines. This paper describes the "FGC Series" coin mechanism for global markets and the "FGB Series" bill validator for global markets that have been developed in consideration of China and the Association of Southeast Asian Nations (ASEAN) region. This paper also presents their respective features and elemental technologies.

2. Background of Development

The Japanese vending machine market has been gradually shrinking recently in terms of both the volume of shipments and sales per unit. Accordingly, the volume of shipments of coin mechanisms and bill validators, which are installed in vending machines, is on the decrease in the same way. Fuji Electric is actively advancing into other automatic equipment markets such as those for payment machines for coin-operated parking lots and ID photo booths. However, this is not sufficient to cover the decline in the vending machine market.

Due to such domestic market conditions, it was necessary for us to depart from the existing products and markets. As a result of analyzing the past expansion of the vending machine market in Japan, we have identified many factors such as the sales strategies and equipment service systems of beverage manufacturers. From the perspective of equipment (coin mechanisms and bill validators), one factor is that they have been able to quickly handle new coins and bills. We have considered advancing into new overseas markets by utilizing this strength.

In Japan, vending machines rapidly became popular along with the country's high economic growth. China is currently in a situation similar to that period in Japan and Fuji Electric has been marketing coin mechanisms and bill validators there since 2004. With vending machines becoming increasingly familiar among Chinese people and the sales and service systems of manufacturers gradually put in place in the last few years, diffusion of vending machines is expected to accelerate. In addition, Southeast Asian countries such as Thailand and Malaysia, although unpredictable, have the potential to see an expansion of the vending machine market in the same way as China, with a lag of a few years. Figure 1 shows Fuji Electric's sales forecast for the coming 3 years in the Chinese market.

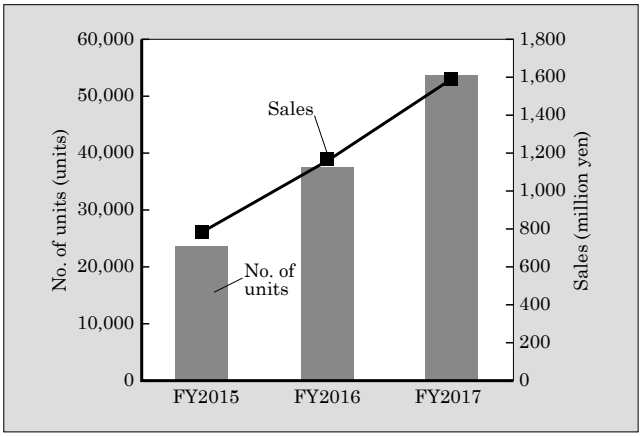

Fig.1 Sales size forecast of Fuji Electric's vending machines in Chinese market

* Food & Beverage Distribution Business Group, Fuji Electric Co., Ltd.

3. Aims of Development and Challenges

For a global launch, we have aimed to standardize as many components as possible and realize a performance equivalent to that of the optimum design for the respective countries. We have made the products compatible with different coins and bills of different countries simply by preparing multiple types of change storage for the coin mechanism and of passage parts of the identifying unit for the bill validator.

4. "FGC Series" Coin Mechanism for Global Markets

A coin mechanism is equipped with functions to identify deposited coins, sort and store them into dedicated tubes and pay out change.

Figure 2 shows the external appearance and configuration of the FGC Series that has been developed. Basically, the mechanism is composed of 4 units and is designed to achieve standardization. It is only necessary to replace some of the components or add an attachment to make it compatible with different countries' currencies. This has made it possible to support currencies of countries that come in small physical quantities.

4.1 Features

We are the first to provide a coin escrow function (see Section 4.3), which temporarily holds the deposited coins, for the FGC Series. Regarding the control method, we have provided interfaces to support both the multi-drop bus (MDB) protocol, which is the mainstream outside Japan, and Japan Vending Machine Manufacturers Association (JVMA) scheme, a Japanese standard.

Table 1 shows the major specifications of the FGC Series.

4.2 New coin validation sensor

The coin validation sensor for judging the authenticity of coins traditionally had a coil sensor that was directly bonded on the housing. With the FGC Series, a bobbin-shaped sensor is soldered on a printed circuit board, which is screwed to the housing. Since it does not use any adhesive, the number of quality control items decreases, leading to improved quality. Figure 3 shows the configuration of the coin validation sensor.

In addition, the new coin validation algorithm with

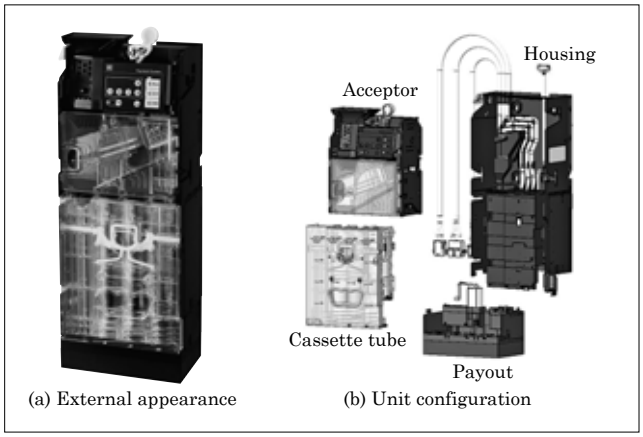

Fig.2 External appearance and configuration of "FGC Series"

Table 1 Major specifications of "FGC Series"

Item		Specification
Applicable coins		Coins of various countries
Coins paid out as change		Coins of various countries
Change storage tube	No. of tubes	5
	Change storing method	Cassette tube method (with attachment/detachment detection)
	Cassette opening/closing function	Provided (with 2-piece cover)
	Tube switching function	Provided (E tube: denomination changeable)
	Locking mechanism	Provided (padlock installable)
Change payout	Payout structure	1 DC motor + 5 clutch SOLs switched in-between
	No. of coins paid out simultaneously	2 max.
	Recovery control	Provided
Coin escrow function		Provided
Drainage structure		Provided (drainage chute installable)
Control method	MDB	Available
	JVMA	Available
	Bill validator connection function	Provided (MDB bill validator)
Power supply	MDB connection	24 V DC ± 10%
	JVMA connection	24 V DC ± 10%
Rated current consumption	Standby mode	0.3 A or less
	Operating mode	1.0 A or less
	Peak	1.5 A or less
Operating temperature range		−15 °C to +60 °C
Dimensions		W138.0×H356.2×D82.3 (mm)
Mass		Approx. 2.0 kg

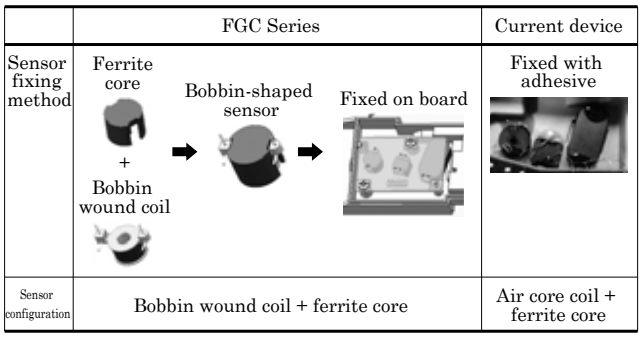

Fig.3 Coin validation sensor configuration

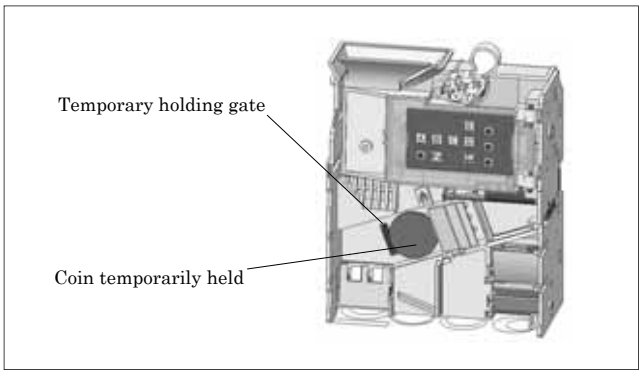

Fig.4 Acceptor unit (with front cover removed)

an enhanced ability to identify ferrous materials offers support for a wider variety of sizes and materials of coins than in the past.

4.3 Coin escrow function

The acceptor unit has a coin escrow function. As shown in Fig. 4, the temporary holding gate holds the coins and, when the return lever of the vending machine is pressed, the coins held are returned as they are. This prevents counterfeit coins from being used. In Japan, this function was devised by Fuji Electric ahead of other companies in the industry. We have developed this technology for the FGC Series to improve the reliability of vending machines, which sell items without any human operator.

4.4 Opening and closing cassette with changeable tube diameter

Coins used in different countries greatly vary in terms of their outer diameter, thickness, material, and other properties. Therefore, we have designed the basic dimensions of the cassette according to the maximum diameter and thickness of such coins. We have made the product capable of dealing with diameters or thickness smaller than the basic dimensions simply by replacing components or adding an attachment.

As shown in Fig. 5, the structure makes it possible to open and close the front and side of the cassette for easy coin replenishment, which is one major feature.

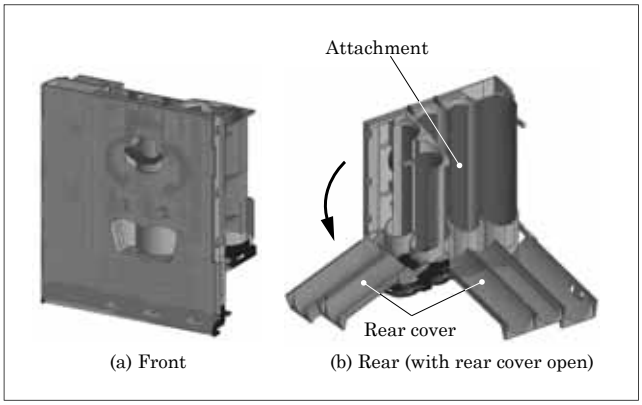

Fig.5 Cassette tube

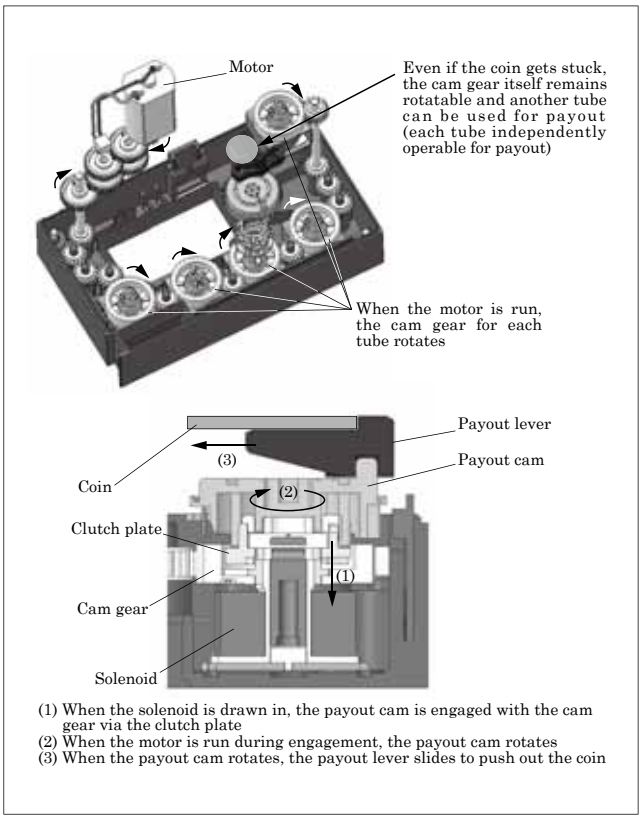

Fig.6 Independent payout mechanism

4.5 Independent payout mechanism

As shown in Fig. 6, a solenoid provided at the bottom of each tube is used to move the clutch plate up and down. This engages and disengages the cam gear and payout cam (green). When the motor is run, the engaged cam gear and payout cam rotate. When the payout cam rotates, the crank mechanism causes the payout lever to slide, which pushes a coin in the change tube for payout.

In this structure, if a coin of the denomination to be paid out gets stuck for any reason, the gear for the tube for that denomination is disengaged by turning off the solenoid. The cam gear itself remains rotatable and turning on the solenoid for another payout tube to engage it allows money to be paid out from an alternative tube.

5. "FGB Series" Bill Validator for Global Markets

A bill validator is a device that identifies, conveys and stores deposited bills. Figure 7 shows the external appearance and configuration of the FGB Series.

To make a bill validator compatible with bills of different countries, technology is necessary that allows the device to identify a variety of bills such as those made of polymers or other non-paper materials. It is also necessary to identify currencies of many different designs and color shades. In addition, technology is required for conveying and storing bills of various sizes.

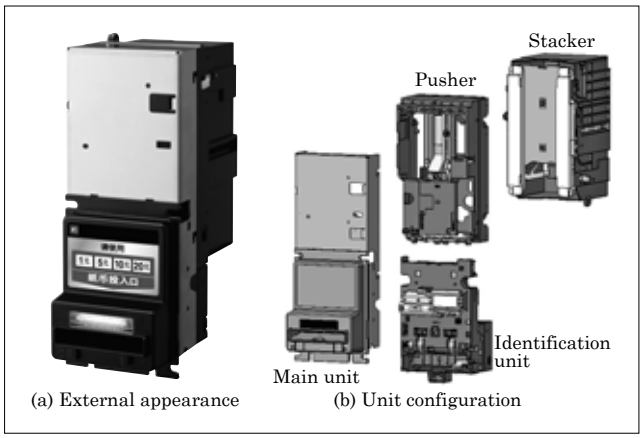

Fig.7 External appearance and configuration of "FGB Series"

Table 2 Major specifications of "FGB Series"

Item		Specification
Applicable bills		Banknotes of various countries
No. of bill insertion slots		1
Insertion orientation		4 longitudinal orientations
Bill conveying system		Automatic pull-in and return by DC motor
Identification time		Approx. 1.4 s
Cash escrow function		Provided (1 bill)
Pull-out prevention function		Provided
Control method	MDB	Available
Power supply	MDB connection	24 V DC ± 10%
Rated current consumption	Standby mode	0.2 A or less
	Operating mode	2.5 A or less
Bill storage		Stack cassette system (removable)
	Locking mechanism	Provided (padlock installable)
Storage full detection		Provided
Bill storage capacity		New notes sealed by government: 600 ± 85 notes Notes in circulation: approx. 400 notes
Operating temperature range		−15 °C to +60 °C
Mounting orientation		Inverted
Dimensions		W94×H246×D127 (mm) *Projections not included
Mass		Approx. 1.2 kg

5.1 Features

For the FGB Series, we have worked on developing products with the focus on the following points in order to deal with a variety of bills of different countries.

(1) Standardized design for series

The basic components and configuration have been standardized to make the product capable of accepting bills of different countries. This can be done simply by changing some of the components, the type of sensor and identification software.

The widths of the bills that can be accepted are 62 to 77 mm. If the width of the passage is specified to be 78 mm to handle 77 mm bills, those with a width of 62 mm may be significantly displaced laterally in relation to the direction of conveyance. Lateral displacement causes the position of the bill that passes over the identification sensor (trace line) to move, making it impossible to read the features of the bill. Providing a mechanism that centers bills is effective but makes the structure complicated.

Accordingly, with the FGB Series, the device has been developed to handle 3 different widths (66 mm, 70 mm and 72 mm) in addition to 78 mm to structurally minimize the lateral displacement. In addition, a line sensor has been used as the identification sensor so that lateral displacement can be corrected with identification software.

(2) Ease of maintenance

There are not as many service bases overseas as in Japan and vending machine installers called operators engage in product replenishment and maintenance. To be able to restore items without difficult maintenance work in the event of failure, a structure that allows operators to easily clean and replace maintenance parts is required. Accordingly, we have designed a structure with the focus on making it easier to replace maintenance parts, as described in Section 5.2.

(3) High reliability

We have realized a structure that accepts banknotes of different countries while ensuring the device's identification performance, which is a fundamental requirement, and reducing bill jams. For the identification performance, we have made use of the simulation technology that evolved with bill validators for the Japanese market to construct an identification algorithm and taken advantage of the sensor correction function. To prevent bill jams, a scheme to reduce the conveyance resistance in bended bills by employing a large roller has been incorporated into the basic design.

Table 2 shows the major specifications of the FGB Series.

5.2 Unit structure of maintenance parts

As shown in Fig. 8, maintenance parts that are not easy to disassemble (such as motors, gears, and conveying rollers) with the current model have been built into a unit for improved replaceability.

Maintenance units are secured with hooks rather than screws and can be removed without tools such as screwdrivers. In addition, any motor speed decrease or roller slip is detected, and an alarm is then indicated on the 7-segment LED on the back. This points to the unit that needs to be replaced before a failure occurs.

In this way, operators can provide high-quality maintenance without requiring special training even

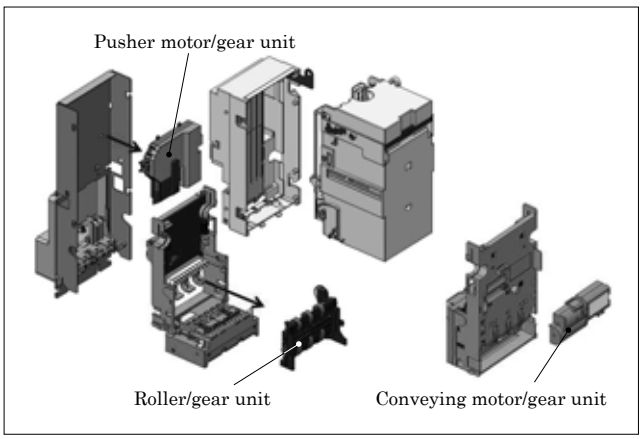

Fig.8 Unit structure of maintenance parts

in overseas bases where it is difficult to secure human resources with advanced skills.

5.3 Adoption of line sensor

With conventional bill validators, in order to meet the market demands for low prices and identification performance, the entire surface of a bill is not traced. Instead, the minimum number of sensors are used and they are composed of light emitting elements with the optimum wavelength and light receiving elements arranged optimally and discretely (discrete sensor method). With the FGB Series, a sensor structure is required that is capable of exhaustively accepting bills of many different countries. An image sensor that scans the entire surface of bills can deal with money from different countries, but is expensive. Accordingly, we have adopted a line sensor to provide a structure that can easily read features of bills of different countries and select the optimum wavelength. Specifically, a pattern that allows up to 12 sensors to be installed is provided. 3- or 2-wavelength sensors can be installed. Figure 9 shows an example of the line sensor's configuration.

5.4 Prism-based bill detection sensor

The concept was not to mount a printed circuit board near the slot to prevent it from water intrusion or damage. Hence, to detect a bill at the insertion slot, we have adopted a system of using prisms to guide the light to the sensor on the printed circuit board in the identification unit for detecting the bill (see Fig. 10).

With this system, the intensity of light decreases before it reaches the light receiving side. Factors in this light intensity decrease include ultraviolet degradation of the material, light intensity degradation due to dust, degradation caused by flaws on the bill conveying surface and degradation due to aging sensors.

With these factors of light intensity decrease taken into account, we have attempted to identify and set a target for the percentage of light guided by the prisms. This target needs to be ensured to allow bills to be detected with a combination of lower limit products of

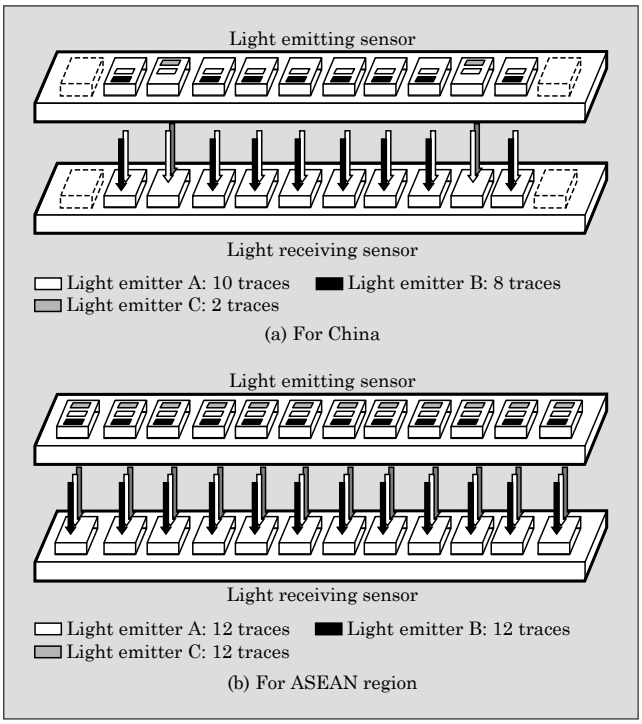

Fig.9 Line sensor configuration

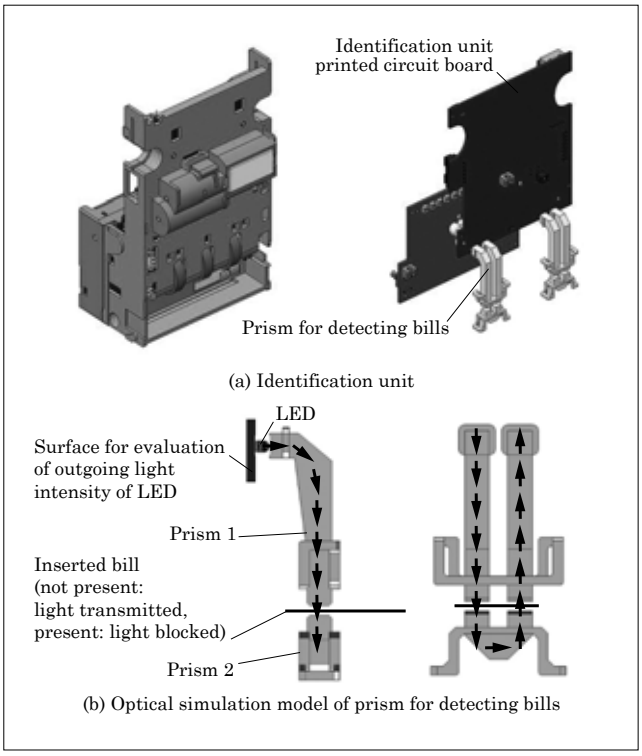

Fig.10 Prism-based bill detection system

light emitting and receiving elements. In this way, we worked on optimizing the shape of the prisms.

In addition, we have modeled related parts and made use of optical simulations to evaluate the outgoing light intensity of the LED. At the same time, we varied parameters such as the material, distance, cross-sectional area, angle of reflection and lens shape,

and made the optimum shape for efficiently guiding and condensing light to ensure the target intensity of guided light.

In this way, we have successfully reduced the number of parts while improving the reliability by not mounting the printed circuit board near the insertion slot and maintained the detection performance.

6. Postscript

This paper has described currency identification devices for global markets "FGC Series" and "FGB Series." In global markets, different specifications including security and ease of handling are required for different countries.

We intend to pursue convenience by further enhancing the products while observing the market trends to contribute to society.