Guarantee-of-Quality Technology for Mechanical Components

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The bill recycling units of Fujitsu ATMs transport notes at a high speed of more than 10 notes per second. The bill recycling units developed by the Mechanical Component Division include 6500 parts and feature an extremely complex control system. Because both newly issued and old notes must be handled, the units must respond to changing conditions of the notes. These units must also be able to respond to changes in such environmental factors as humidity. Prior to assembly, we check and guarantee the functions of each part of these units, in addition to evaluating product reliability and stability as for other Fujitsu products. This paper describes the quality assurance techniques employed by the quality assurance division from the development evaluation stage of the mechanical components to the commercial production stage by using the example of a bill recycling unit.

1. Introduction

As shown in **Figure 1**, there are four types of mechanical components installed in an ATM unit: a passbook printer for printing in passbooks, a card unit for reading and writing cards, a coin unit for dispensing and receiving coins, and a note unit for dispensing and receiving notes.

Each of these units is subjected to individual function and performance evaluations, and reliability assurance tests. Upon passing these tests, the units are installed in an ATM. Then the ATM itself is subjected to a reliability assurance test to guarantee its performance and quality.

The reliability assurance test involves more than 50 prescribed test items including a noise application test (covering static electricity, lightning surges, and impulses), environment test (temperature and humidity), vibration test, and dust test. All products must satisfy these test items prior to shipment.

Operation tests using actual passbooks, cards, notes, and coins are then conducted to evaluate stability. After the stop and failure rates acceptable for an ATM are ascertained, the unit is deemed acceptable for shipment. ATM quality is largely determined by whether the four units that handle passbooks, cards, coins, and notes were successfully developed.

This paper describes the quality assurance techniques of the mechanical components employed by the quality assurance division by using the example of a bill recycling unit.

2. Mechanical component evaluation

The bill recycling unit (hereafter called the note unit) transports notes at a high speed of more than 10 notes per second. In addition, the note unit includes 6500 parts and features an extremely complex control system.

Pulse motors, DC motors, electromagnets, and various sensors are mounted at various locations. These devices are used to control

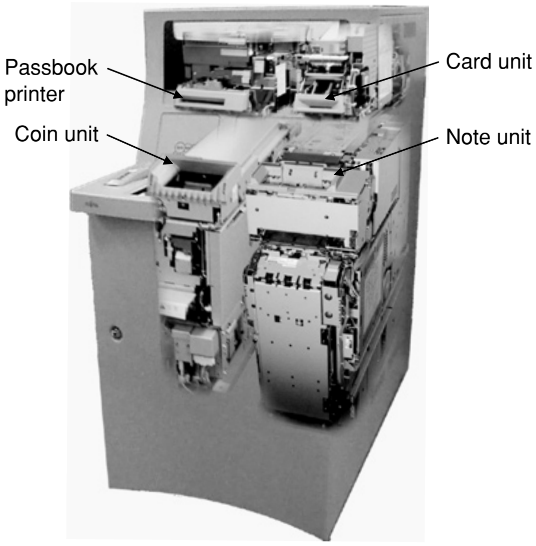


Figure 1
Fujitsu ATM FACT-V model 20.

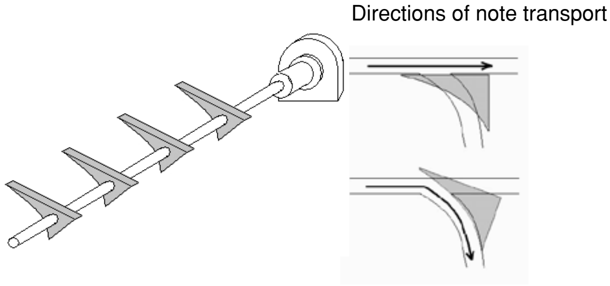


Figure 2
Gate used to divide notes.

the rubber rollers, note transport belts, and note-dividing gates to handle at high speed the notes being deposited or dispensed. The note unit is considered completed once each individual function has been checked and verified.

Inside the note unit, notes are transported at a high speed of more than 10 notes per second. With each note weighing one gram, 2500 notes stored in the cashbox inside the note unit weigh 2.5 kg. The difficulty of development evaluation and the accumulated technical expertise are concentrated in the mechanical components used for handling this large number of notes at high speed. The following sections describe the tools used to analyze and evaluate the operation and functions of mechanical components.

1) Optical displacement measuring instrument and laser displacement measuring instrument

These measuring instruments are used to analyze the switching speed and behavior of electromagnets and other components.

2) Doppler tester

The Doppler tester measures the acceleration and rotational unevenness of rotating components. The Doppler tester is used to analyze the behavior of the pulse motors.

3) High-speed camera

The high-speed camera is used to analyze the disbursement, transport, and storage status of notes, coins, and passbooks.

3. Analysis of mechanical component operating speed

As shown in **Figure 2**, the gate that divides the notes consists of plastic guides aligned on a metal shaft. A rotary-type electromagnet attached directly to the gate controls the guide. The required switching speed is determined based on the note transport speed and number of notes to be handled per second. For the note units installed in ATMs for domestic use, demands require a gate operating time not exceeding 20 ms. This operating time is measured and, if handling of the notes takes more than the required time, improvements must be made. The general method of improving the note-dividing gates involves weight reduction by changing the shape of the gate.

Each note unit is currently equipped with 13 gates to divide the notes. The operating speed of all 13 gates is measured.

Because the note-dividing gates are switched in a short distance at high speed, optical displacement and laser displacement measuring instruments are used for these gates.

1) Optical displacement measuring instrument

The optical displacement measuring instrument is a non-contact, behavior analysis device.

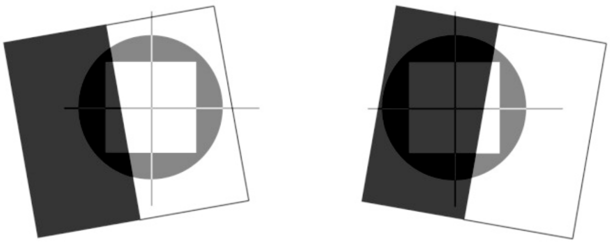


Figure 3
Proportion of black and white inside lens.

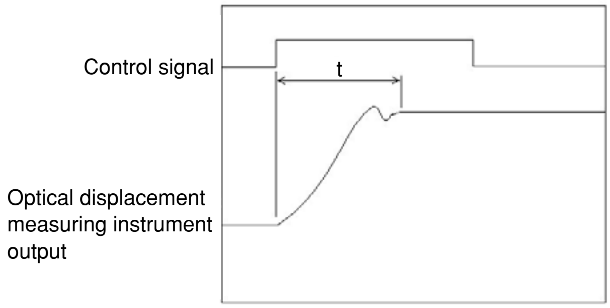


Figure 4
Measurement example.

This measuring instrument applies a target divided into white and black portions to the object to be measured, and then outputs as a voltage the proportion of white and black viewed as the object passes by the lens.

The white and black target is attached to the end faces of the note-dividing gates. As shown in **Figure 3**, when the gate begins to operate, the output value of voltage changes as the proportion of white and black viewed by the lens changes. This voltage is input together with a control signal from the gate magnet into an oscilloscope in order to observe such behavior as operating time and the presence or absence of bounce.

Figure 4 shows a measurement example. The gate switching time (t) is measured. If the time is not within the required time, improvements must be made such as changing the shape of the gate (for weight reduction).

2) Laser displacement measuring instrument

A laser displacement measuring instrument is used to perform the same measurement as described above. A target need not be attached regardless of the material of the object to be measured. The basic measurement method is the same as described above.

4. Control optimization of mechanical units

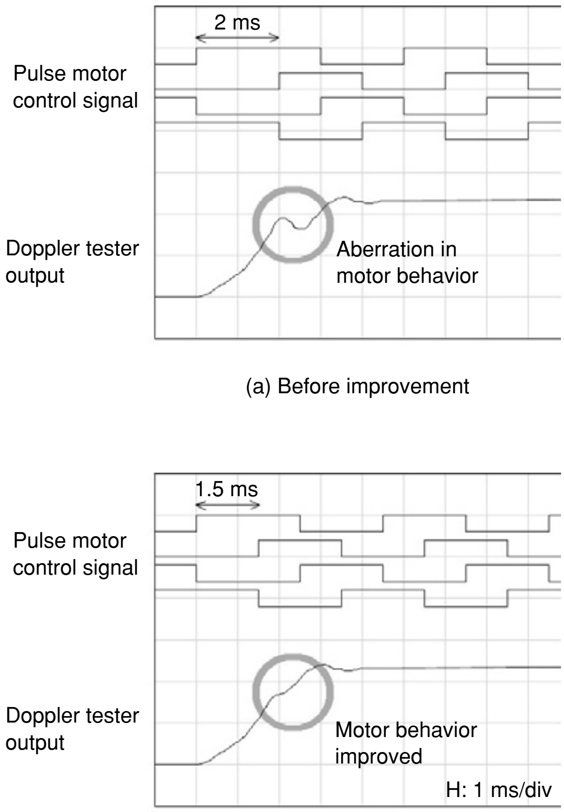
Pulse motors are often used in controlling mechanical units. They are frequently used for such purposes as moving parts by a predefined amount or monitoring a sensor to stop a part precisely at the sensor location. The note units installed in ATMs for domestic use have 23 pulse motors.

Control methods such as 2-phase excitation or 1-2-phase excitation are used to control the pulse motors. However, it is often necessary to individually set the pulse frequencies (hereafter called slewing) at starting and stopping, depending on the load balance. At development evaluation, the behavior of all pulse motors relative to slewing at starting and stopping must be observed, and the optimum slewing set. A Doppler tester is used to measure this behavior of pulse motors.

The laser Doppler vibrometer is a non-contact, behavior analysis device. The laser Doppler vibrometer directs laser light emitted from a probe onto a test object and measures such items as the acceleration and rotational unevenness of the test object. The tester also outputs a voltage proportional to the speed of the test object.

In pulse motor behavior analysis, control is optimized by inputting the output value and phase signal of the pulse motor control to an oscilloscope and observing any discrepancy between the motor axle operation and phase signal.

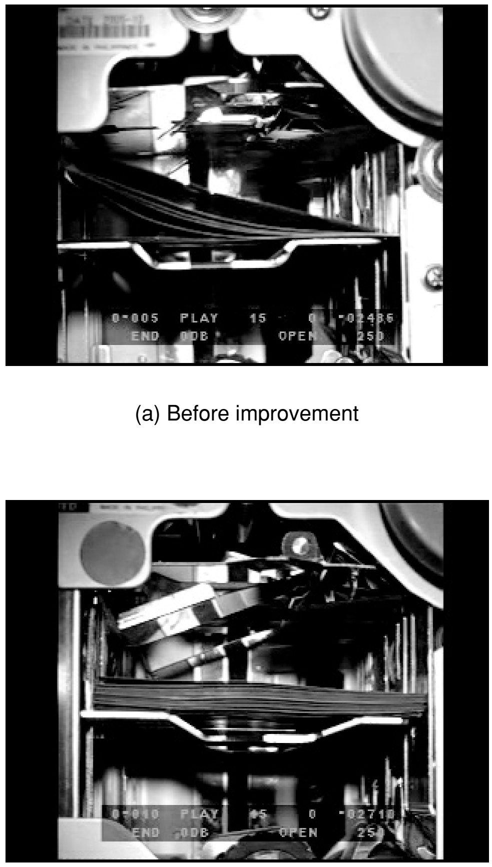
Figure 5 shows an example of improving motor behavior. In this example, a movable guide is controlled using a pulse motor. The initial



(a) Before improvement

(b) After improvement

Figure 5
Improvement in motor behavior.



(a) Before improvement

(b) After improvement

Figure 6
Analysis of note behavior by using high-speed camera.

slewing settings were 20→2→1→1. Observing the behavior revealed some aberration and agitation in the motor axle before switching the phase signal at motor activation. Therefore, changing the slewing settings to 20→1.5→1→1 improved motor behavior.

5. Media behavior analysis

Changing the behavior of such media as notes, coins, and passbooks can significantly impact quality. In particular, notes and coins often cause trouble due to unpredictable behavior. Here, a high-speed camera must be used to observe media behavior and the shapes of such parts as the guides designed to stabilize media behavior.

The high-speed camera can record images at a resolution exceeding 1000 frames per second. The previous method used was to record the images on special video tape. However, the images can now be recorded in internal memory, reproduced using a PC, and saved in MPEG format.

Figure 6 shows an example of analyzing behavior when notes are stored in the cashbox. In the example, the behavior of notes being continuously stored in the cashbox was observed. The storage guide was then improved so that notes leaning against the inside wall in the cashbox are neatly stacked in the storage area.

Figure 6 (a) shows the behavior of notes before the improvement. The notes stored from the upper right are stacked to lean against the inside wall in the cashbox. By changing the

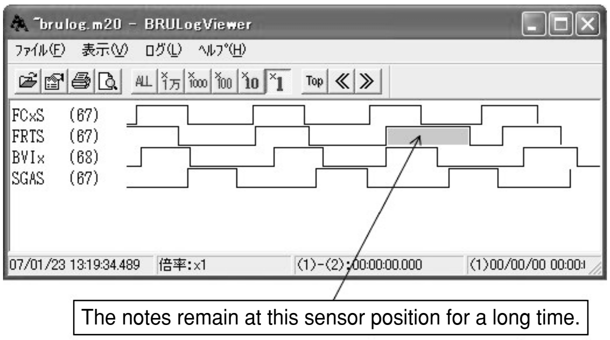


Figure 7
Example of log analysis.

shape of the guide inside the cashbox, the notes are neatly stacked in the storage area as shown in Figure 6 (b).

6. Failure analysis

As mechanical unit quality has been improved and the number of failures reduced, it has become more difficult to reproduce a particular failure. It therefore takes much longer to identify the cause of failure and devise an appropriate countermeasure. To also handle failures that do not occur frequently, the mechanical unit is provided with a logging function to record its operational behavior.

The logging function records errors that occur in the mechanical unit during operation tests and shipment tests, and whenever the notes jam. A PC is connected to the mechanical unit to download the log. Dedicated analysis software is then used to convert this log data for identifying the circumstances under which the error occurred.

Figure 7 shows an example. In the example, the log results of four sensors (sensor output results) are displayed. Here, the output result of each sensor consists of high and low levels. The high level indicates the state where light is interrupted by a note and not detected by the sensor. The low level indicates the state where light is not interrupted and detected by the sensor.

7. Conclusion

This paper described some quality assurance techniques employed for mechanical components. There are many other quality assurance techniques available besides those described in this paper. For example, a highly reliable media transport system and magnetic head control must be assured to read or write to the magnetic strips on passbooks and cards. To differentiate between notes and coins, the most advanced hardware and software techniques are used, with quality assured in the same way.

ATMs are devices that process notes, coins, passbooks, and cards that are directly inserted by the customer. However, ATM quality can also be significantly influenced depending on the condition of notes, coins, passbooks, or cards. In addition, environmental conditions (e.g., temperature, humidity) can largely impact quality. For example, fluctuations in humidity and the amount of static electricity in the air greatly affect the stiffness of notes.

One mechanical unit is considered completed once the functions of each of the unit's parts are checked and verified. Although such individual work does not stand out, the technologies accumulated through these down-to-earth efforts for quality assurance stand behind the approximately 40 000 Fujitsu ATMs currently in operation throughout Japan.

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Mr. Okiji graduated from the department of Electrical Engineering at Kumano Technical College, Mie, Japan in 1982. He joined Fujitsu Ltd., Kawasaki, Japan in 1982, where he has since been engaged in evaluation activities for newly developed ATM mechanical components and quality assurance technologies.