Deck Unit Assurance System

Koichi Ikinaga
Shinichi Ohi
Ai Masunaga
Kyoko Tajima
Eiko Nakanishi
Takashi Yamakawa

Traceability system

x̄-R control system

Abstract

The changer deck, a key component of Fujitsu Ten products, previously combined a variety of complex functions in its structure. In the new CH-5, a wide range of design improvements were performed, in which an improved design structure was achieved with the four basic functions integrated into each unit.

To ensure this design, it is necessary to implement a production procedure in which the functions and capabilities of each unit are ensured individually, rather than examining the completed product, with the units then assembled into a fault-free product.

In order to achieve this, we developed a manufacturing support system (including suppliers) that achieves the collection and uniform control of important dimensions and special characteristic data, real-time trend control utilizing measurement data, automatic detection of process errors based on FUJITSU TEN manufacturing standards and simultaneous notification of related departments, understanding of countermeasure status, sharing of data throughout the organization, and the understanding of manufacturing history from parts, to units and completed products (traceability).

This report outlines the automation technology and data processing technology utilized by Fujitsu Ten to achieve these goals.

1 Introduction

While precision and complexity of the changer deck, a key component Fujitsu Ten product, have increased with miniaturization, it is important to continue to offer high-quality products stably.

Thus with the newly developed CH-05, we have introduced the principle of complete "unitization" as a measure to improve quality. This refers to a structure in which the following four functions to be achieved by the changer deck are allotted respectively to each unit, and the function is completed in each unit independently.

1) Music playback function
2) Disk insertion/ejection function
3) Disk change function
4) Disk storage function

With this structure, functions and performances can be checked individually for each unit in the manufacturing process, and assured units can then be assembled into a completed product. Thus reliable fault-free production is enabled, and the process yield is improved. In addition, quality and reliability are improved for the customer by implementing sequential connection (traceability) of assurance records, from components to units to completed products. However, a corresponding revolution in the manufacturing process is necessary in order to realize this concept.

Thus development of the "deck unit assurance system" to be introduced here was implemented in order to cope with manufacturing needs for realization of the aforementioned manufacturing process, and the needs of the design department to understand data in real time regarding the onsite production conditions at separate locations, due to production site globalization.

After first identifying the form of manufacturing process control required for unitization, this document provides an overview and introduction to the features of the "deck unit assurance system", which was first introduced in the Fujitsu Ten group at TIANJIN FUJITSU TEN ELECTRONICS CO., LTD. in July 2005.

2 Overview of system development

2.1 Deck manufacturing process for unitization

The aforementioned form of deck manufacturing process control required for unitization is shown in Figure 1.

The primary features of this manufacturing process control are shown as follows.

1) Measurement inspection and trend control ($\bar{x}$-R control) at each process.

In precisely driven equipment such as a deck, "variance" arising in components and assembly process will have an effect on the precision of the stop positions for movable components, and on the operating load. For this reason, rather than a simple pass/fail determination, proactive prevention is realized through measurement of "variance" on a daily basis, implementation of trend control, and delivery of feedback to the previous process.

2) Unified control of trend control data from components to units to completed products

The whereabouts of the causes of problems can be quickly discovered by a unified search of trend control data by product function. In addition, sharing of informa-

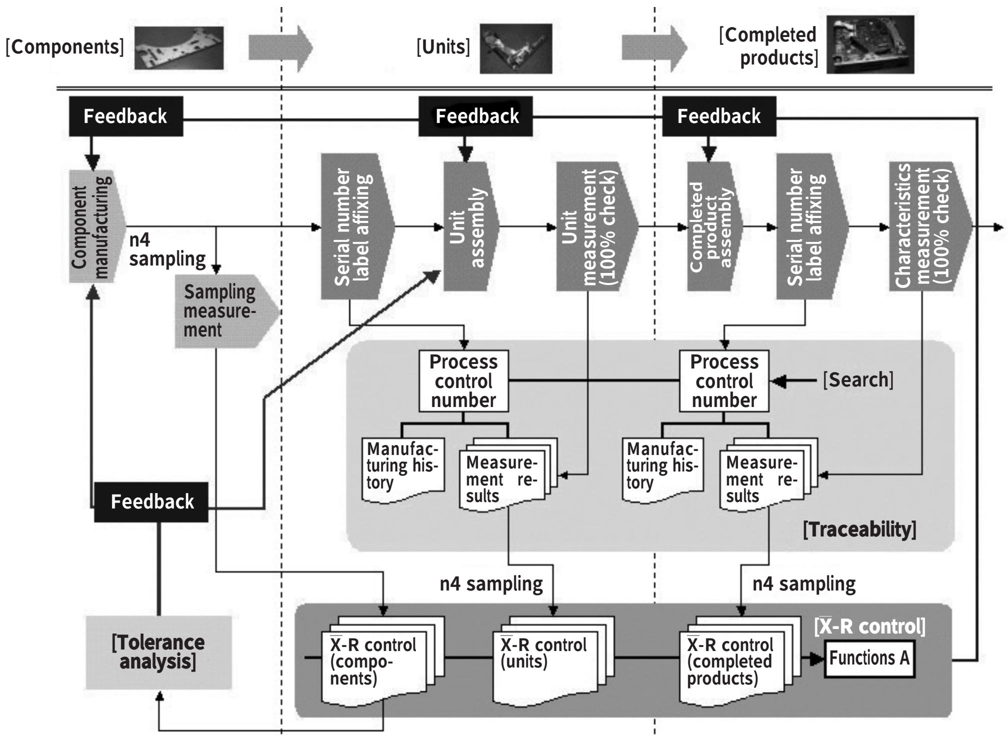


Fig.1 Deck manufacturing control process for unitization

tion across the organization is enabled by unified control.

3) Input of measurement values for components to the tolerance analysis(1) and prior calculation of unit assembly conditions (dimensions)

For prior calculation of actual unit variance, actual measurement values for component variance, rather than so-called 1Cpk hypothetical values, are input into tolerance analysis which has been utilized for product design in recent years. In this way, feedback on components and unit processes is enabled prior to unit assembly, enabling further improvements to proactive prevention for faults at the deck manufacturing site.

4) Traceability at the unit level

The unique process control number conventionally affixed to deck completed products is also affixed to each unit, and is related to inspection records measured in process. In this way, confirmation of manufacturing history for each unit is enabled via completed product or unit process control numbers, which may be used as basic data for analyzing the causes of faults.

2.2 System issues

In order to achieve manufacturing process control with the our features mentioned above, systematization of information for the manufacturing line becomes necessary. The preconditions for creation of this system have been arranged:

- **Component manufacturing is by suppliers outside the company, while unit and completed product manufacturing is in-house.**
- **Multiple measurement points of units and complete products**
- **Ensuring flexibility of manufacturing line layout and process changes**
- **Self-concluding process/multiproduct mixed production**
- **Recovery enabled for network problems**
- **Line non-interruption with system problems**
- **Quality records control enabled (strict adherence to TS16949)**

In order to realize a system satisfying these conditions, attention was given to the following issues:

[$\bar{x}$-R control, and tolerance analysis]

A) Ensuring multiple import routes (outside the company and in-house) for measurement values

B) Efficiency of registration work

C) Diverse displays supporting speedy investigation of causes

D) System promoting reliable process control

[Traceability]

E) Preventing wrong operation (fool-proofing)

F) Preventing line stops when there are system problems

G) Preventing line stops when there are network problems

H) Flexible response to process changes, etc.

Commercial systems satisfying these requirements were investigated, but even when individual requirements were satisfied, nothing available satisfied them all. For this reason, the system was realized through in-house development.

(1) Tolerance analysis
CAE (Computer Aided Engineering) implementing summated calculations of component dimensions and geometrical variance (tolerance), thereby calculating variation in the assembled form.

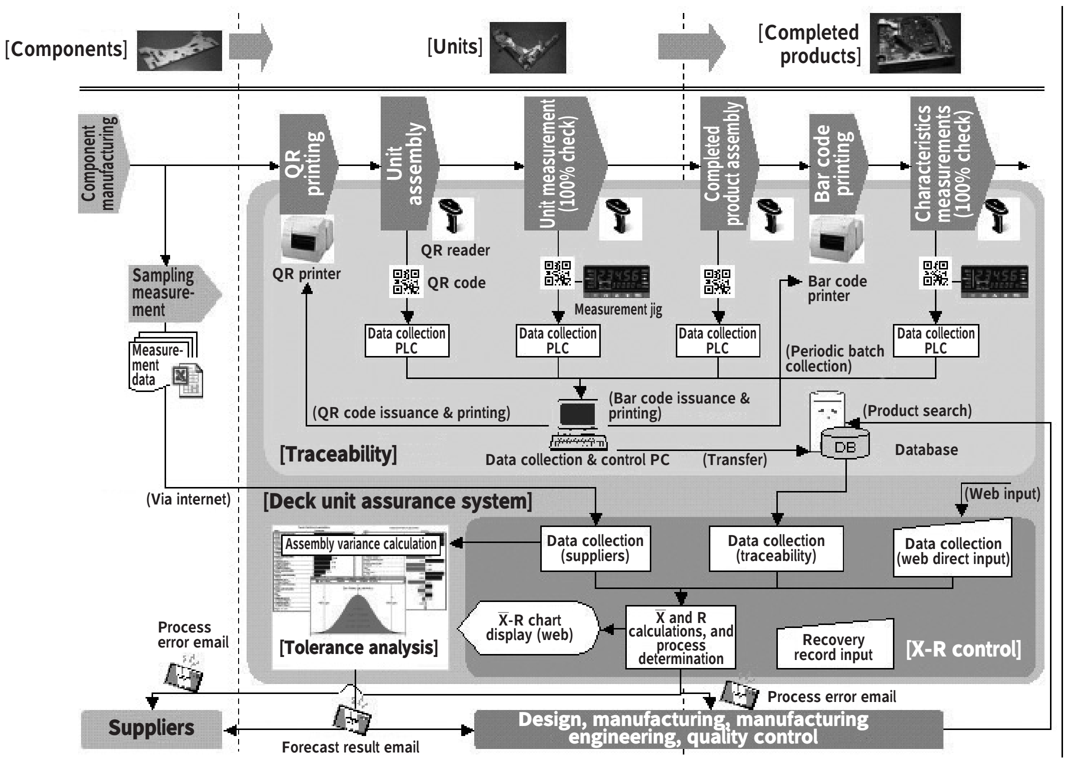


Fig.2 Overall system

2.3 Overall system

The deck manufacturing process and overall Deck unit assurance system are shown in Figure 2.

Beginning with $\bar{x}$-R control, data of components procured from outside the company are imported via the internet, while units and completed products data is imported from databases written by data collection PLCs (programmable controllers) placed at manufacturing sites (or by manual data input in web terminals), and there are unified. Based on this data, $\bar{x}$-R charts of all measurement items are displayed on the web, and processes are evaluated in accordance with the rules. If worsening trends are noted, a process error email is sent to related personnel, encouraging investigation of causes and implementation of countermeasures. The system is arranged such that these records must be input into the system (creation of a closed loop). Implementation of this sequence of operations is completely automated.

In the tolerance analysis, the actual component data collected for $\bar{x}$-R control is input into the analysis models created during product design, allowing practical assembly variance to be forecast. In this way, feedback to component processes and unit processes is enabled prior to unit assembly (Figure 3).

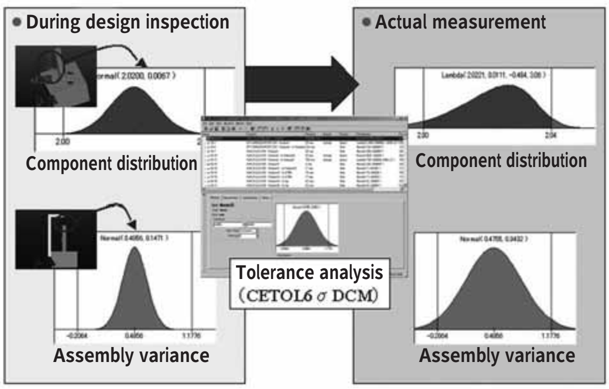


Fig.3 Tolerance analysis

Functions for the inputting of actual values are built into the tolerance analysis software. However, cooperative development was implemented with the software manufacturer in order to enable fully automated execution, from current measurement values entry to the output of results.

Next, in terms of traceability, QR codes[2] denoting the process control number are affixed to units prior to unit assembly. These are used as keys and are linked to manufacturing history (manufacturing date, operation shift, work group and staff) and measurement values. Further, they are also linked to each unit and completed product, and are amassed in a database.

The current system development is positioned as a 1st step. It has achieved the introduction of the $\bar{x}$-R control system and the traceability system. In terms of tolerance analysis, development has been completed of the software itself, but incorporation into this system has yet to be implemented. Thus in the next section, techniques which solved the aforementioned issues in the two systems that have been introduced will be explained.

3 $\bar{x}$-R control system features

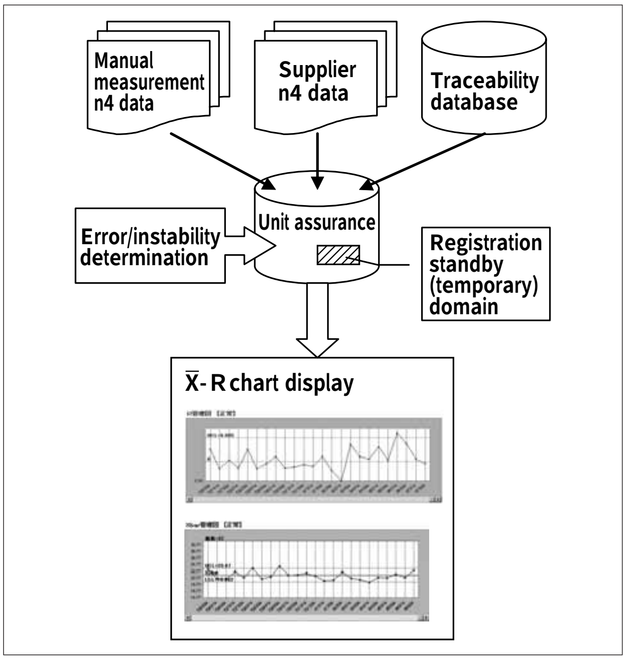
3.1 Ensuring multiple import routes (outside the company and in-house) for measurement values

Data used by the $\bar{x}$-R control system can be registered as mentioned above, according to the following three routes: (Figure 4)

1. File registration by web screen (measurement record input conventionally performed through manual

2. Automated import of data from outside the companies (import from suppliers)

3. 4 data (n4) extraction from traceability databases (this is the $\bar{x}$-R standard number of sampling) and automated transfer.



"Error/instability determinations" are as per FUJITSU TEN Manufacturing Standards FMB-002.

Fig.4 Data collection image

Data registered separately via these three routes is consolidated within the system and then collectively controlled. In this way, a deck unit assurance system has been realized, allowing us to relate together and sequentially understand the three trends with respect to supplier components, in-house units and completed products.

Behind the data transfer from the traceability system, the resolution of technical issues involving overseas and Japanese bases has been a significant factor. This is due to the increase in communications freedom for the Japanese and overseas networks brought by the independence (flattening) of the overseas network in 2004.

(2) QR code® is a registered trademark of DENSO WAVE INCORPORATED.

3.2 Efficiency of registration work

Flow of registration work

I Registration of product (unit) configuration information

Configuration information download (APROS)
Configuration information upload (the system)

↓

II Registration of measurement point and data

Measurement information registered to the applicable configuration number
(Characteristics, measurement items, specification values, classifications)

I Registration of product (unit) configuration information

First, configuration information (component list) to be controlled is registered in the system. In terms of configuration information, it is equipped with an import function for information from FUJITSU TEN's PDM (Product Data Management) system "APROS"(3), and is set up so that registration is completed simply through download files from APROS and upload them to the system. (Figures 5, 6)

Fig.5 Screenshot of APROS configuration information download

Fig.6 Registration screen

II Registration of measurement point and data

Measurement point information from the configuration list is registered with respect to each components and units. In terms of measurement points, as multiple details can be input on a single screen, the interface enables confirmation of all measurement points during registration. (Figure 7)

Fig.7 Registration screen of measurement location

The registration details for each measurement point are as shown below:

- **Characteristics (dimensions, time, power, current, voltage, other)**
- **Measurement items (names of measurement points)**
- **Specification values (standard values, upper limits, lower limits, units)**
- **Classifications ($\bar{x}$-R control, tolerance analysis)**

As standard values registered here are particularly important for $\bar{x}$-R control, the system has been equipped with numeric value error prevention functions.

3.3 Diverse displays support speed-up of cause identification

The system has been prepared with the various screens shown below, in order to speed up onsite cause investigation:

A) Error/instability point list on top screen (Figure 8)
B) $\bar{x}$-R chart (normal and error results) (Figures 9 and 10)
C) Related component list (Figure 11)
D) Keyword search results (Figure 12)
E) Countermeasures past history / registered model list, etc.

Fig.8 Error/instability display on top screen

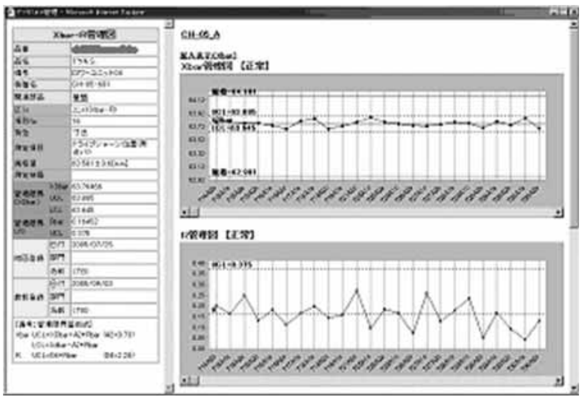


Fig.9 $\bar{x}$-R chart display (normal result)

(3) APROS
FUJITSU TEN's original PDM (Product Data Management) system.

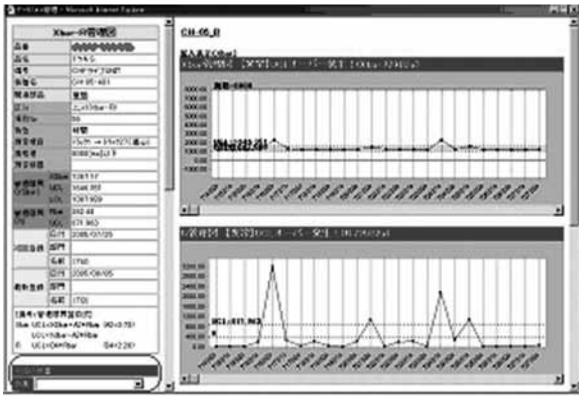


Fig.10 $\bar{x}$-R chart display (error result)

Fig.11 Related component List

Fig.12 Display example of search results

3.4 Structure promoting reliable process control

If errors or instabilities arise in a process, warning notification (e-mail) is issued automatically from the system to all related personnel, and a recover input field is additionally displayed on the $\bar{x}$-R chart screen (Figures 13 and 14). As the changer deck, the focus of this system, is manufactured in China (Tianjin), care has been taken to include both Japanese and Chinese languages, so that staff in either country can understand the details.

In addition to the abovementioned error recovery functionality, the following mechanisms have been installed in order to prevent neglect of investigation of causes and countermeasures.

When an error or instability occurs, all measurement data imported from that point is stored in a registration standby region (Figure 4). Determinations and output to graphs are not executed. Further, on the top screen, error/instability displays are maintained until recovery input is complete (Figure 8). Then, when the system has been in a condition where the subsequent data can be received (recovery input is complete), the measurement data stored in a separate region is immediately moved from the storage location to the formal measurement data region, which is then followed by execution of error/instability determination. In this way, "error/instability" are not neglected. Rather, when countermeasures are complete and have been registered, the subsequent data is immediately reflected via highly responsive system functionality.

Fig.13 Warning notification (alarm mail)

Fig.14 Recovery input field

In addition, the system can be used to forecast current conditions and to take countermeasures while checking on recoveries to date, by referring to past recovery history previously registered. (Figure 15)

Fig.15 Recovery history

Through the functions listed above, problems such as mistake judgment arising from human's monitoring and error judgment, insufficient understanding of supplier control conditions, input mistakes and omissions from manual data input, insufficient countermeasures and potential with respect to errors and instability, and other types of concerns for quality assurance due to reliance on human attention spans may be eliminated.

The results of this $\bar{x}$-R chart system are summarized below:

- **Centralized control and online sharing of measurement values**
- **Automatic measurement and automatic recording (in some processes)**
- **Supplier measurement values also controlled (understanding trends).**
- **Instant automatic determinations based on manufacturing engineering standards**
- **Simultaneous e-mail delivery (warning notification) when an error occurs**
- **When countermeasures have not been implemented, warning remains on the top screen**
- **Sharing of information throughout the organizations**
- **Enables understanding of manufacturing history from components to units to completed products**

4 Features of the traceability system

As explained in section 2, it was necessary to solve the following issues in order to realize traceability in the deck unit assurance system:

1. Preventing wrong operation (fool-proofing)
2. Preventing line stops when there are system problems
3. Preventing line stops when there are network problems
4. Flexible response to process changes, etc.

Solution of these issues was achieved by creating the system within a local network, making use of PLCs often used in FA (factory automation) systems, and then installing the various functions to be described below. An explanation will now be given of the system configuration. (Figure 16)

The system comprises the following 3 major elements. Each element is connected via LAN, creating a single network.

(1) Trace Station (hereinafter TS):

Functions for QR code reading, and linking with measurement instruments. It comprises a reader for QR code reading, a controller for data interchange and a display for displaying error messages, etc.

(2) Server:

The database server stores all history data within the plant. Master data for system operation is also stored.

(3) Data collection PC:

A program is installed (hereinafter referred to as Promas) which is equipped with functions for TS operational control, data collection and transfer to the server.

When the system is operating, QR code affixed to the unit is first read by TS 2-dimensional code scanners (Figure 16 left). Next, process control number data which corresponds to the read QR code, is stored in the controller together with the measurement values imported

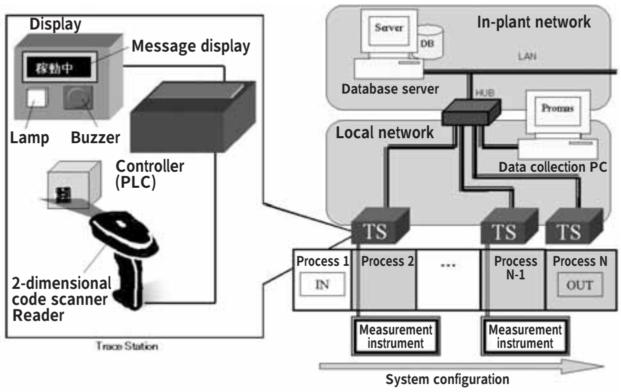


Fig.16 System configuration

from the measurement instruments. A single TS is installed in each process to implement history control. Data acquired by each TS is collected as needed by the data collection PC, and is transferred to the server at desired intervals. (Figure 16 right)

4.1 Preventing wrong operation (fool-proofing)

Utilizing the data read from the QR code, the system conducts incorrect product checks and prior process incompletion checks, thus achieving prevention of wrong operation.

- **Incorrect product checks:**

Checks whether or not it is the right type of unit for the current operation.

- **Prior process incompletion check:**

Checks if products should not be processed because they are mixed in from another line or are products for which the prior process was incomplete.

The operation flow, including fool-proofing functions, is shown in Figure 17.

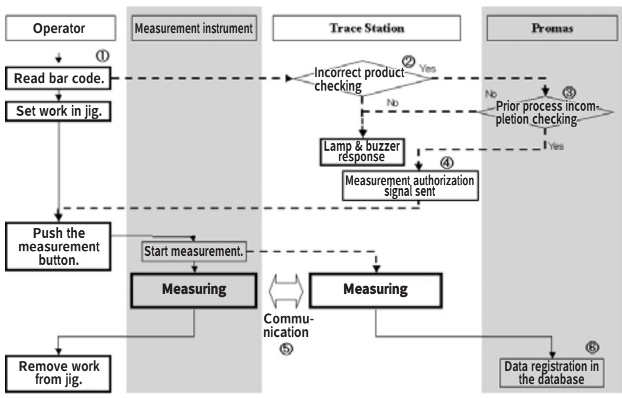


Fig.17 Operation/system flow

①Workers read the QR code affixed to the unit with the 2-dimesional scanner connected to the TS.

②The model code given to the process control number is checked, thus carrying out incorrect product checking.

③The process control number acquired from the TS is compared with the prior process history stored in the data collection PC, thereby carrying out prior process incompletion checking.

④The measurement authorization flag is transferred to the measurement instrument.

⑤The measurement instrument carries out measurements, and transfers the measurement values and measurement results to the TS. The TS transfers acquired measurement data to Promas

⑥This data is stored into the database together with the previously acquired process control number.

4.2 Preventing line stops when there are system problems

At the manufacturing site, manufacturing line interruption due to system problems is a critical event. Accordingly, an algorithm was devised to allow production to continue without stopping the line, even in the event that errors, network interruptions or other problems arise with the system.

During measurement, measurement jigs and TS can operate independently. As the measurement jigs have no effect on the operation of TS, it appears to the worker as though only the measurement jigs are operating, and are not needlessly burdened by the intricacy of the system. The only handshake necessary between measurement jigs and TS is the measurement authorization signal sent from the TS. However, when a problem arises with the system, it may become impossible to send this authorization signal.

Thus, a switch button has been prepared for manual transfer of an authorization signal so that independent measurements can be implemented by only the measurement jigs. By switching connections to the measurement jig with the alternative button, measurement without TS is enabled, and the process does not stop (Figure 18).

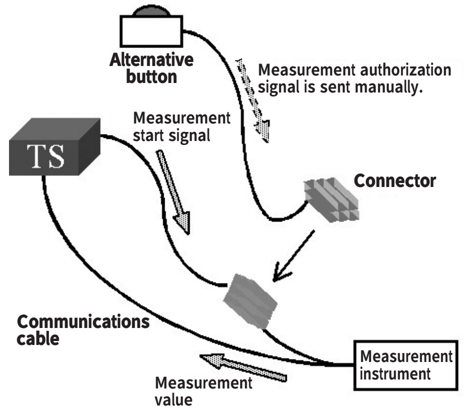


Fig.18 Connections between trace station and measurement instrument

4.3 Preventing line stops when there are network problems

As previously described, Promas is equipped with functions allowing it to collect data from the TS and to transfer the collected data. In addition, Promas acquires master data from the server at system start-up, and saves it to the data collection PC. Conversely, there may be plant network interruptions due to problems with network equipment. If network faults or server faults arise, communications between Promas and the server will become impossible. However, system local network operation will be enabled by using the stored data on the data collection PC. In addition, when connection with the server is intermittent, the history data for which transfer to the server failed will be retransferred at the next transfer opportunity. The system is thus also arranged so as to preserve the sense of real time history data inspection.

4.4 Flexible response to process changes, etc.

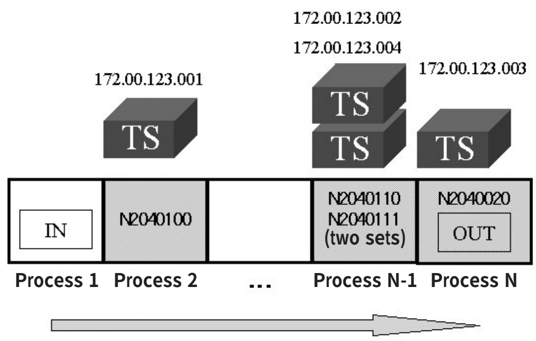
In order to realize traceability, it is necessary to installed traceability facilities in manufacturing lines, and to connect a number of cables. When there are manufacturing line layout changes or process changes, reinstallation or reconnection work arises. To reduce the burden of such work, the following three measures have been used in system configuration, enabling flexible response to process changes.

4.4.1 Reduced wiring and independence of each TS via IP address allotment

Promas recognizes TS by the IP address allotted to each TS. As TS is treated as one of the network devices, a single LAN cable can be used for wiring. If each cable is connected via a Hub, a network with Promas can be created easily regardless of the number of TS connections. In addition, as each is individually independent, the form of the wiring does not matter.

4.4.2 Station Code

Recognition codes referred to as Station Codes are allotted to each process on the manufacturing line. By linking the Station Code to the TS IP address, it becomes possible to understand which IP addressed TS is controlling which process history (Figure 19). In addition, when two same processes exist (there are two measurement instruments), these two processes can be recognized by adding a number to the last digit of the Station Code. When processes are newly increased on the manufacturing line, the Station Code is newly issued. By using the Station Code, all processes can be uniquely recognized.



IP Address	Station Code
172.00.123.001	N2040100
172.00.123.002	N2040110
172.00.123.004	N2040111
172.00.123.003	N2040020

Fig.19 Links between TSs and station codes

4.4.3 Flexible setting of history control process order

The order of process for which manufacturing line history control is implemented can be changed in accordance with manufacturing line layout changes and additions to the history control process. Thus flexible response is enabled to changes in process order, by using Station Code and reference tables of the history control process order. An example is shown in Figure 20.

Process order	Station Code
1	N2040100
2	N2040110
2	N2040111
3	**N2040020**

2 and 3 process order switched →

Process order	Station Code
1	N2040100
2	**N2040020**
3	N2040110
3	N2040111

Fig.20 Flexible setting of history control process order

In the actual system, when history control process additions, additions of the number of process, and changes to history control process order are implemented, processes are added and changed on the master data maintenance screen of the system. Changes to process order are completed simply by restarting Promas, enabling instant response to changes (Figure 21).

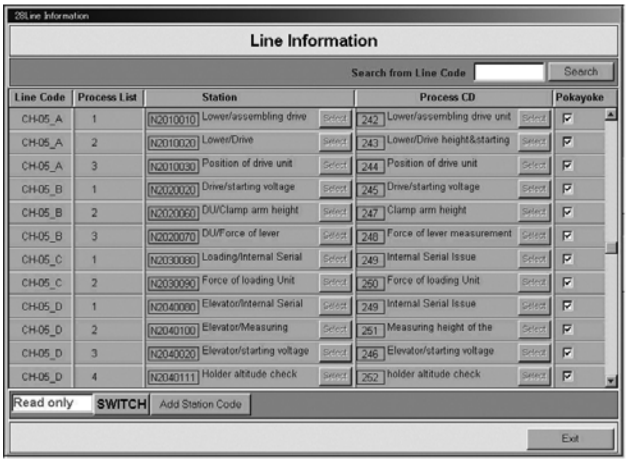


Fig.21 Master data maintenance screen

5 Conclusions

This document has introduced the features of the two systems currently developed and introduced onsite.

Through the introduction of this system, changes to in-process variance and detection of errors prior to fault occurrence have been enabled whenever and wherever, providing a substrate for preventative measures. However, in addition to this system (hardware), analysis know-how (software) is necessary in order to implement process analysis and improvements before faults have occurred, using only trend data within with scope of control.

In future, tolerance analysis function will naturally be incorporated into the system, analysis know-how will be accumulated at manufacturing sites, and continuous follow-up will proceed through the Deck Unit Assurance WG[(4)], the group responsible for initially promoting the system development, so as to achieve work measures effectively operating within a close loop.

Finally, I would like to extend my heartfelt thanks to the WG members and everyone at TIANJIN FUJITSU TEN for their cooperation and guidance in development of this system.

(4) Deck unit assurance WG:
A working group comprising members from the Deck Engineering Department, Inspection Department, Engineering Support Department, FTIS, Global Production Promotion Center, Manufacturing Engineering Department and Production Engineering Department.

References

1) Fujimoto et al. Development of the Miniaturized Indash CD Changer Deck (CH-05), Fujitsu Ten technical Journal, Vol. 45 (2005).

Profiles of Writers

Koichi Ikinaga
Entered the company in 1993. Since then, has engaged in process development and CAE promotion. Currently in the Production Engineering Department of Production Group.

Shinichi Ohi
Entered the company in 1993. Since then, has engaged in promotion and development of traceability systems. Currently in the System Development Department of Fujitsu Ten Information Systems Limited.

Ai Masunaga
Entered the company in 2004. Since then, has engaged in development of traceability systems. Currently in the System Development Department of Fujitsu Ten Information Systems Limited.

Kyoko Tajima
Entered the company in 2000. Since then, has engaged in information system establishment. Currently in the Engineering Support Department of Research & Development Group.

Eiko Nakanishi
Entered the company in 1997. Since then, has engaged in information system development. Currently in the Engineering Support Department of Research & Development Group.

Takashi Yamakawa
Entered the company in 1981. Since then, has engaged in system development of automatic inspection. Currently the General Manager of the Production Engineering Department of Production Group.