Technology Introduction

Installation of a Flexible Manufacturing System for Transmission Pumps

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1 Introduction

During the initial stage of the transmission vane pumps (hereinafter "PV") business, we planned to produce a number of PVs for CVT[Note 1)] of the same design/geometry. Then, we built a high-speed, large-lot manufacturing system to reduce the cost of manufacturing.

However, today's customer needs have diversified. To match such a variety of needs, there has been a tendency to manufacture more types of product in smaller quantities (Fig. 1).

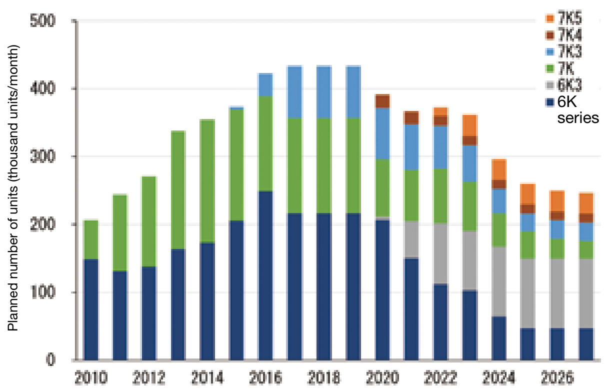

Fig. 1 Global production of CVT PV

If we tried to implement mixed production of the increasing number of product models using the existing high-speed, large-lot manufacturing system, we needed to extensively modify the system, thereby incurring high costs for production preparation. Since it was also difficult to reduce the number of production lines because then only a limited number of models could be subjected to mixed production, lower production efficiency or higher cost of manufacturing was anticipated if we received less orders for the product.

Under this situation of the transmission PV business, we received from a customer an order for a new model that was considered as the last CVT PV. On the other hand, in the course of the activity for "departure from heavy reliance on a single customer", which is one of our business policies, we received for the first time an order from a second customer for a new product, a PV for AT[Note 2)].

Note 1) Acronym for Continuously Variable Transmission.
Note 2) Acronym for Automatic Transmission.

As a result, we became busy with many frequent events while developing a new CVT PV and a new AT PV. In addition, the geometry and machining details of these products were not compatible with their conventional counterparts (Fig. 2), which made it difficult to additionally manufacture them on the existing lines in operation. Then, we needed to add flexible production lines partly because of the necessity of global CVT restructuring.

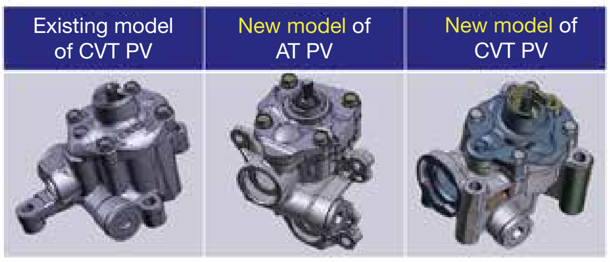

Fig. 2 Pump geometry

2 Purpose, Targets, and Requirements

2.1 Purpose

In preparing a manufacturing system for the new models of AT PV and CTV PV, the Production Engineering Dept. carried out activities with the purpose of "establishing a compact, flexible manufacturing system that can accept mixed production of various models and allows labor saving".

2.2 Targets

While maintaining quality, we set a cycle time of 40 seconds, which is twice the conventional time, based on the number of units of inquiry. The personnel and investment targets were set to 1/2 of the conventional values. The processing cost targets for the three processes of body machining, cover machining, and assembly were set to be no higher than the conventional values.

To implement flexible manufacturing, targets were also set for set-up time and production preparation cost for additional models.

Furthermore, we set space requirements for the installation of process equipment. We aimed to be able to apply these requirements for enhanced space efficiency to all production sites (Table 1).

Table 1 Targets for production lines

	Body machining	Cover machining	Assembly
Cycle time	40 sec./unit	40 sec./unit	40 sec./unit
Line personnel	One person/shift	One person/shift	Two persons/shift
Operational availability	Not less than 78%	Not less than 78%	Not less than 85%
Set-up time	20 min. or less/ session	20 min. or less/ session	9.5 min. or less/ session
Production space	Three processes to be included in a global PV area (10 m x 28 m)		

2. 3 Requirements

To achieve the targets, the following four requirements were established:

1. A manufacturing system built in a global PV area Note 3) shall be able to be introduced at any production site.
2. Set-up work shall be able to be conducted efficiently and safely.
3. A traceability system also supporting manual transport shall be established to prevent outflows of non-conforming products and to store quality records.
4. The required contamination level shall be maintained.

Note 3) A unified manufacturing area for all production sites of pump business units.

3 Activities

Related departments discussed the manufacturing processes. They reviewed the processes on the premise that the line transport is manually done by operators with priority placed on the flexibility of the production lines and that automation for ensuring quality and productivity is implemented for each production equipment.

3. 1 Simulation

Through process design reviews (DRs) and repetitive discussions with related departments, we reviewed various combinations of tasks together with the Production Dept. and KPS Note 4) Improvement Dept. and performed repeated simulation using corrugated cardboard Note 5) (Photo 1).

Note 4) Acronym for Kayaba Production System.

Note 5) Make simulation equipment from corrugated cardboard and pipes to simulate transport and set-up works.

Photo 1 Simulation using corrugated cardboard

3. 2 Layout Review

Conventionally, the body machining, cover machining, and assembly lines were allocated to separate areas and occupied a layout space of about 2.5 global PV areas.

To build a manufacturing system with a more efficient use of line space and with a high degree of freedom for equipment installation applicable to any production site, we reviewed the layout with the aim of putting three lines in a global PV area (Fig. 3).

We placed importance on flexibility so as to support a variety of product geometries. For this purpose, we decided to select manual transport by operators, instead of the conventional automatic in-process transport.

We allocated a group of operators to the machining zone involving quality concerns and another group to the inspection process and then leveled out the tasks. As a result, the personnel target was achieved even for manual transport, making it possible to build a manufacturing system that can ensure both quality and flexibility.

Furthermore, we worked with the Production Control Dept. to determine the optimal layout of the parts inlet and product outlet chutes, achieving both efficient in-line work of operators and a straight material transport route (Fig. 4).

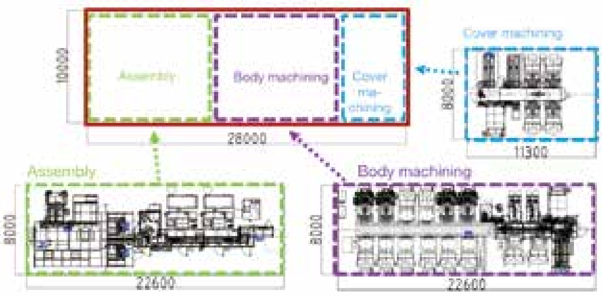

Fig. 3 Layout before review

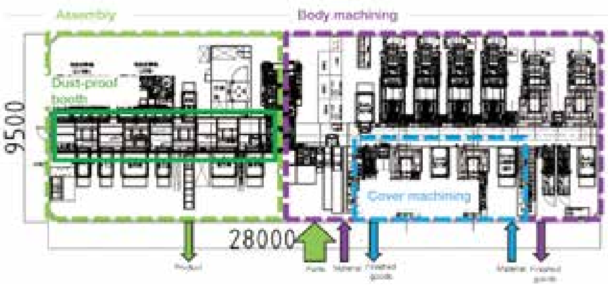

Fig. 4 Layout after review

3. 3 Process Integration

In order to put the three lines in the layout space described above, we conducted process integration for each of the processes as follows, achieving the space target.

3. 3. 1 Process Integration of Machining Equipment

To achieve process integration, we introduced small work clamps as machining jigs. This substantially downsized the machining jigs, achieving a shift from the conventional machining process using flat jigs to a process using cradle jigs Note 6) (Fig. 5).

This shift enabled multi-face machining. The conventional six processes needed to accomplish machining were integrated into four processes. The fewer processes helped reduce the time of manual handling work, while the higher degree of freedom of jigs enabled easier set-up changes for other models.

Note 6) A mechanism in which swinging the jig like a cradle will enable machining not only in a single direction but also at different angles.

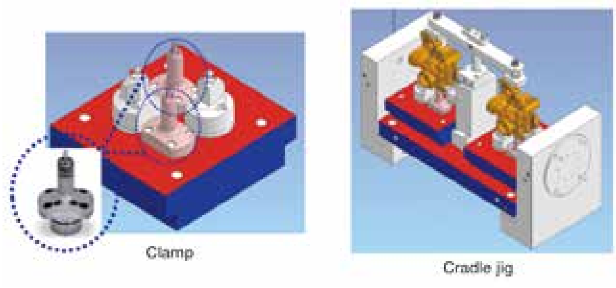

Fig. 5 Machining jig

3. 3. 2 Process Integration of Assembly Equipment

We reviewed the process allocation within the cycle time setting of 40 seconds and decided to integrate two to three processes into a single equipment unit. This integration helped reduce the number of equipment units used and the number of attachments/detachments, contributing to lower processing cost. We also ensured mountability and a wider moving range of the set-up jigs so as to accommodate various product geometries and specifications that vary by model.

As examples of process integration of assembly equipment, the following describes plug and cover bolt tightening processes.

The AT PV uses three plugs of two different types. These plugs need to be tightened in three directions. To accept plugs in different orientations, we provided the plug tightening machine with a cradle mechanism to allow work to swing around the Y-axis and another swing mechanism to allow work to swing around the X-axis, in addition to the regular X-Y axes.

We also installed a socket changer in the equipment to enable automatic socket changes without the need for a set-up change by an operator, making it possible to tighten multiple types of plugs in a single equipment unit (Photo 2).

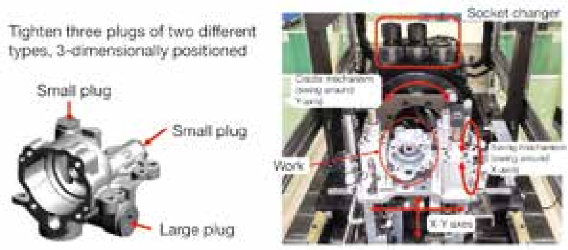

Photo 2 Plug tightening machine

The cover bolt tightening process needed to accommodate different bolt pitches that varied by model. We provided the nut runner with multiple moving shafts to accommodate cover bolts in various positions without mechanical set-up work (Photo 3).

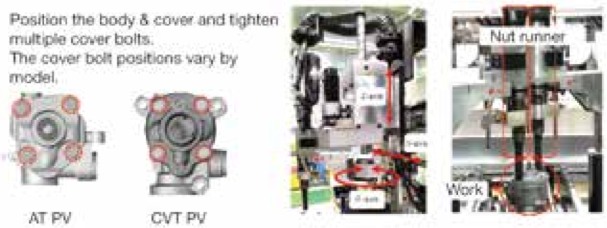

Photo 3 Cover bolt tightening machine

3. 4 Quality Improvement Measures

When building a new manufacturing system this time, we also tried to maintain or improve the quality level of the conventional manufacturing system.

3. 4. 1 Establishment of a Traceability System

We achieved traceability by engraving a serial number for identification on individual body/cover parts in the leading process of the machining line and by reading the serial number of all workpieces with cameras (Photo 4) installed in the processes from machining to assembly.

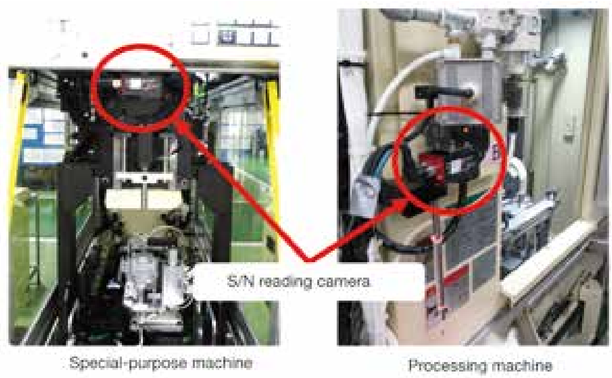

Photo 4 Serial number reading camera

In this system, the serial number read in individual processes is written to the edge PLC Note 7) along with information about the product model and process progress as well as a timestamp. The next process reads the information from the edge PLC to identify the condition of the previous process, preventing a process skip or outflow of non-conforming products.

Note 7) A programmable logic controller (PLC) for primary processing between the manufacturing system and the server that collects and stores data. It is intended to reduce the server load and increase the processing speed.

Furthermore, quality data output from equipment units is automatically stored in the server, preventing inappropriate behavior such as data falsification (Fig. 6).

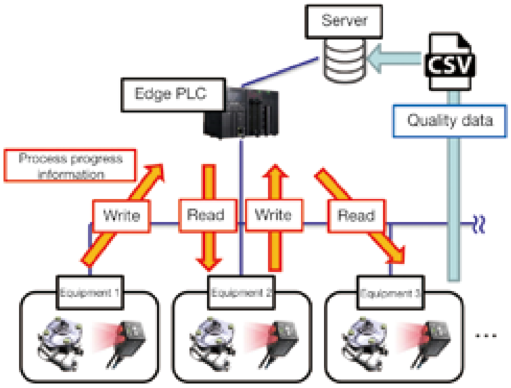

Fig. 6 Traceability system

In the machining process, MT-LINKi Note 8) was introduced as an equipment monitoring system. This monitoring system obtains a history of thermal changes per cycle, enabling the prediction of possible causes of lower machining accuracy and determination of the dimensions during dimensional adjustment.

This system has also allowed system users to obtain information about the equipment condition and alarm history during production, thereby enabling non-operating analysis without relying on hearing from operators (Fig. 7).

Note 8) MT-LINKi is a registered trademark of FANUC CORPORATION.

Fig. 7 MT-LINKi screen

3. 4. 2 Contamination Quality Control

While we built a manual transport production system that is totally different from the conventional high-speed, large-lot manufacturing system, we decided to maintain the conventional contamination quality control.

In the machining process, a preliminary cleaning before the inspection and distribution processes removes chips and cutting fluid. This cleaning is intended to improve the inspection accuracy and prevent carry-over of such contaminants to subsequent processes.

To satisfy the contamination standard for the products, we added a palletization process to the last part of the machining process. In the palletization process, an operator puts all parts for a unit of the product into a cleaning pallet to be cleaned immediately before assembly (Photo 5).

Through this process, we prevented the occurrence of missing or excessive parts in the assembly process and improved the contamination level by reducing the work in process after cleaning.

Photo 5 Cleaning pallet

4 Results

We successfully installed the three production lines (body machining, cover machining, and assembly) in a single global area as planned.

Mass production was launched in December 2021 for AT PV and in April 2023 for CVT PV. The production has continued so far with no complaints.

We also achieved the productivity and line personnel targets, namely, a cycle time of 40 seconds/unit and four persons/shift respectively.

The operational availability target was achieved in the machining process, but not achieved in the assembly process on a monthly average basis. Continual improvement is under way to achieve the target (Table 2).

Table 2 Results of newly-installed production lines

	Body cover machining		Assembly	
	Targets	Result	Targets	Result
Cycle time	40 sec./unit	40 sec./unit	40 sec./unit	40 sec./unit
Line personnel	Two persons/ shift	Two persons/ shift	Two persons/ shift	Two persons/ shift
Operational availability	Not less than 78%	84.5%	Not less than 85%	78.9%

5 In Closing

We have successfully built a manufacturing system based on a new concept. This system is now used to manufacture two models of AT PV/CVT PV that have just been designed.

We will manufacture more product models in the new manufacturing system, hoping that the system will be a "flexible manufacturing system" in the true sense of those words.

Finally, we would like to take this opportunity to deeply thank all those concerned who extended support to this project.

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