Technology Introduction

Incorporation of Processing of Base Plates for Piston Motors into FMS Lines

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1 Introduction

As excavators in the Chinese construction equipment market have become larger, there has been a demand for boosting production of large excavators. Under this situation, KYB Corporation has received more orders for piston motors (Fig. 1) manufactured in its Sagami Plant (Fig. 2). It was decided to establish a plant-wide production system in Sagami Plant, requiring enhanced production capacity for the base plate (the part in red shown in Fig. 1). Another demand was to reduce the selling price while needing to develop competitive products. To increase the profit margin, it is essential to carry out activity to reduce the cost of the base plate that accounts for a substantial proportion of the product cost.

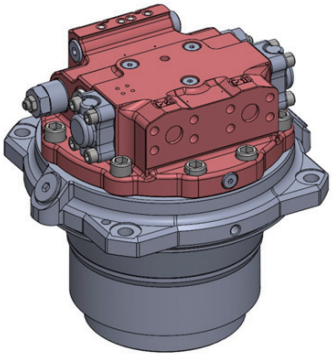

Fig. 1 Piston motor

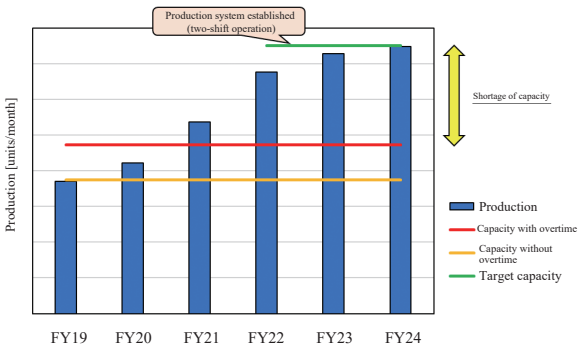

Fig.2 Projected production of base plates and production capacity

2 Purpose

To achieve the target manufacturing cost of the cost reduction activity and to establish a new production system for base plates.

3 Targets

- Manufacturing cost	Down 22%
- Base plate production capacity	Up 66%

4 Requirements

[1] To cut back capital investment by optimizing production lines.
[2] To implement preventive maintenance using sensing technology and internal automatic evaluation of machining centers.
[3] To ensure the process capability for precision deep hole drilling.

5 Overview of Lines

The base plate processing line consists of a machining process with machining centers (hereinafter the "MC") and a finishing process including deburring, inspection, honing, surface grinding, and jet cleaning. Among these, the MC machining process may use the serial (Fig. 3) or parallel (Fig. 4) processing line configuration depending on the number of types of work. These lines have the following features:

[1] Serial line

Fast processing line with less set-ups for limited types of work.

[2] Parallel line

FMS-based Note1) line with less set-ups for a variety of work. The use of FMS allows the production of many different parts and unattended operation. Fig. 5 shows the FMS operation screen.

Note 1) Acronym for Flexible Manufacturing System.

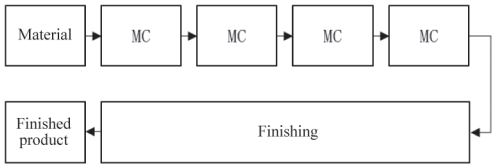

Fig. 3 Overview of serial processing line for base plates

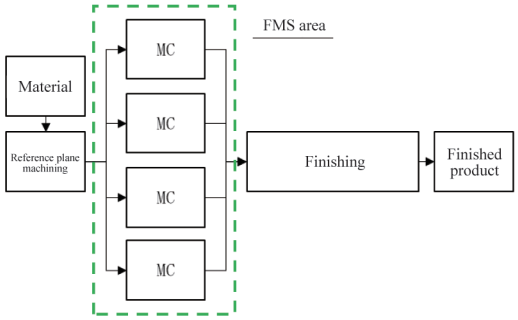

Fig. 4 Overview of parallel processing line for base plates

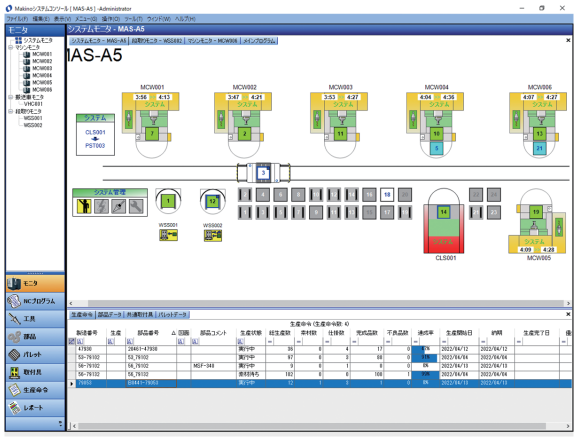

Fig. 5 FMS operation screen

6 Implementation

6. 1 Optimization of Production Lines

6. 1. 1 Overview of Improvement

To establish a base plate production system, an approach was introduced that added two more MCs to the existing parallel line to achieve the target cost and the target production capability. Before deciding on the approach, two proposed approaches were compared with each other: one was to add equipment to the existing serial line and the other to add equipment to the existing parallel line, because building a brand new line required huge capital investment.

6. 1. 2 Results of Comparison of Proposed Approaches

Table 1 shows the results of the comparison. The serial and parallel line approaches had their own advantages and disadvantages and both approaches could satisfy the target production capability. In this project, the parallel line approach was selected because it was judged to be able to satisfy the target cost with a minimum number of equipment units with no time loss for dividing the processing time.

Table 1 Comparison of proposed approaches

Item		Mark	Proposal [1] Serial line	Mark	Proposal [2] Parallel line
Characteristics		—	Fast line with less set-ups	—	FMS-based line with less set-ups for a variety of work
Machine model		—	MSF-340 *One model	—	MAG-14 to MSF-340 *11 models
Quality	Quality	×	Positioning is required in each process. Some processes cannot be divided to ensure the precision requirements.	○	Single-chuck machining. Not so affected by the positioning accuracy.
Cost	Additional equipment	×	3 units	○	2 units
	Extra personnel	—	+1 person/shift	—	+1 person/shift
	Manufacturing cost	×		○	
Productivity	Processing time	×	Division of processing time causes time loss	○	No division of processing time, no time loss Minimum tool changes
	Set-up	○	A single product requires no extra set-up	×	Extra small set-ups in finishing process
	Initial and final pieces check	○	Only parts machined in the relevant process to be measured	×	All machined parts to be measured in each equipment unit
	Piecework	○		×	
Others	Advantages	—	Less vulnerable to process trouble	—	Relatively easy to increase capacity with additional equipment
		—	Simple physical and information flows	—	Easy to implement unattended operation due to long processing time
Total evaluation		×		○	

6. 2 Automation of Jig Inclination Measurement and Automatic Internal Evaluation

6. 2. 1 Current Problems

The base plate is subject to a stringent tolerance for the squareness between the reference plane and the bearing bore. To maintain the accuracy, it is essential to always achieve the squareness of work to the MC spindle (Fig. 6). Conventionally, operators have tried to ensure the accuracy by manually measuring the accuracy of the MC spindle and jig. However, such manual measurement involves destabilizing factors including misadjustment, mismeasurement and forgetting to measure.

6. 2. 2 Automatic Measurement Using Touch Sensor

Higher capital investment leads to higher cost. Then, we built a software program to automatically measure displacement and evaluate equipment accuracy by using the touch sensor installed in the MC process. The following describes the measurement flow and Fig. 7 shows the flow chart of the measurement program.

[1] If the last accuracy measurement was in the previous month or earlier, proceed to the measurement sequence (monthly measurement)

[2] Using the touch sensor, measure the reference plane of the jig that is clamping work (Fig. 8).

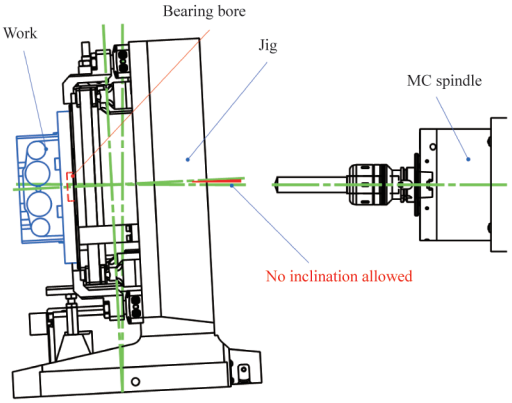

Fig. 6 Positional relation between work and MC spindle

[3] If the measurement result is within the specification limits, proceed to the machining sequence. If the result is out of the limits, issue an alarm to urge operators to take remedies.

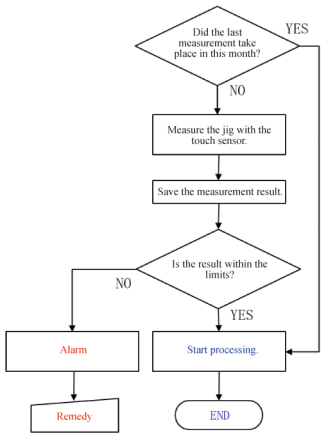

Fig. 7 Flow of measurement program

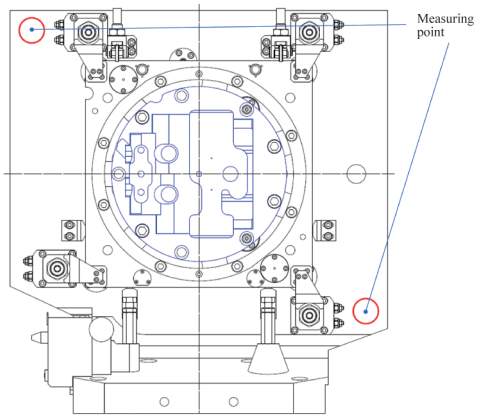

Fig. 8 Measuring point of touch sensor

6. 2. 3 Verification of Proposed Approaches

We compared the measurements of actual work with the jig specifications because we could not directly measure actual work. We determined that the measurements satisfied the work specifications when they met the jig specifications (Fig. 9).

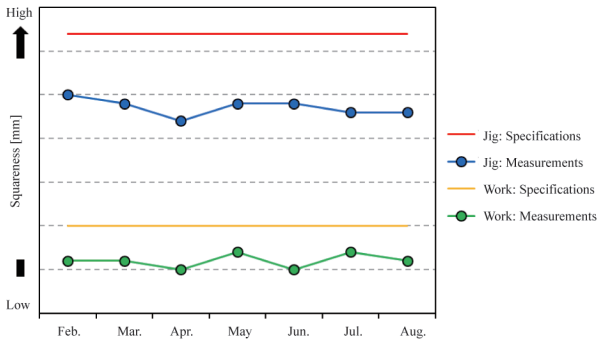

Fig. 9 Relation of measurements between jig and actual work

6. 3 Ensuring Process Capability by Improving the Honing Stone

6. 3. 1 Current Problems

The spool bore, which is an important part of the base plate, is roughly machined in the MC process and then finished by the honing machine. In the initial quality check, however, the process failed to meet the spool bore cylindricity requirements. A comparison of cylindricity before and after honing revealed that the cylindricity actually worsened after honing (Figs. 10 and 11).

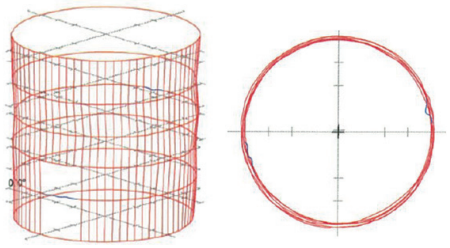

Fig. 10 Before honing

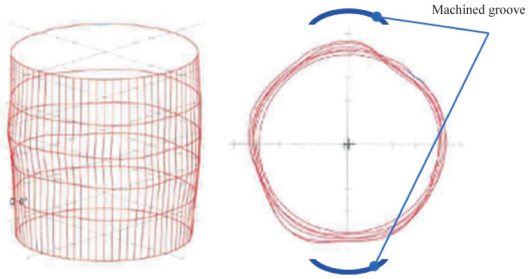

Fig. 11 After honing (before improvement)

6. 3. 2 Causes of Lower Honing Accuracy

A cause investigation identified two possible causes of lower honing cylindricity:

[1] Bore profile specific to the base plate

Fig. 12 shows the cylindrical section of the spool bore. Problems occurred in the parts c and d in Fig. 12. In the relevant parts, the circumference of the circle is partially grooved. The presence of the machined grooves affects the processing area, resulting in substantial variations in cutting load.

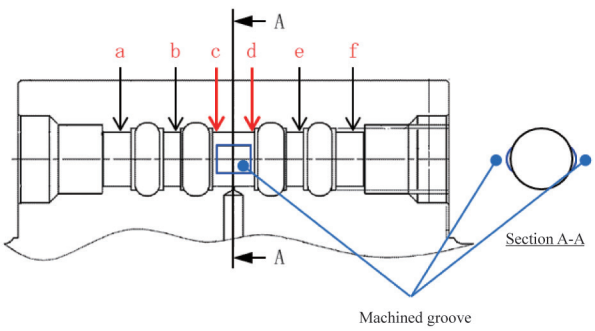

Fig. 12 Section view of spool bore

[2] Hardness of the bond of honing stones

Adjustment work must be carried out every time the honing stone is replaced. So, a relatively hard bond has

been conventionally used to extend the stone change cycle. While the service life of the stone has certainly been longer, the self-sharpening effect has been reduced, worsening the honing performance.

6. 3. 3 Improvement of Working Accuracy by Changing the Stone Bond

As mentioned above, there has been a conventional tendency that relatively hard bond is used to extend the stone life. To address the problem that dull stones are used to hone the parts with substantially variable cutting load, it was decided to use a softer bond. The use of softer stone bond improved the self-sharpening to ensure that new abrasives are always exposed. This has improved the honing performance, achieving stable processing not depending on the work profile.

6. 3. 4 Verification of the Proposed Approaches

A verification of the accuracy after improvement has determined that the cylindricity has been substantially improved (Fig. 13). Furthermore, a quality check after continuous processing (N = 20) has determined that the cylindricity, which had been around the upper limit of the specifications, was substantially improved, satisfying the process capability requirements (Fig. 14). Despite the concern with the softer bond, the stone adjustment time per replacement has been shorter. The total tool change time has remained the same because the frequency of stone replacement has increased.

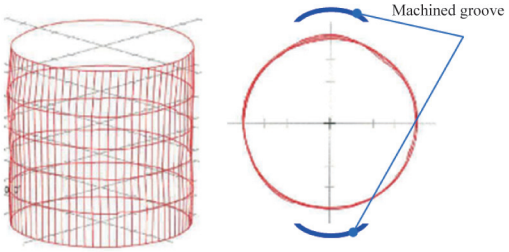

Fig. 13 After honing (after improvement)

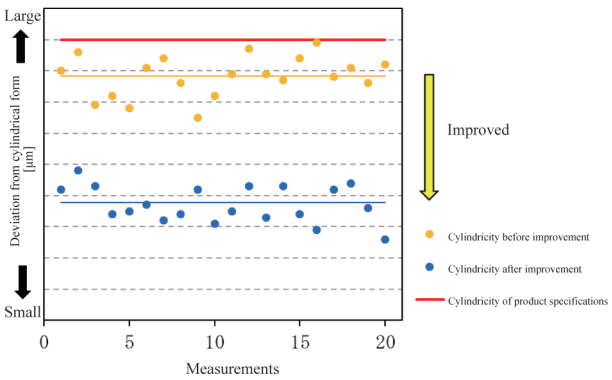

Fig. 14 Cylindricity before and after improvement

7 Results

Table 2 shows the results of the improvement.

Table 2 Results of improvement

Item	Target	Result	Evaluation
Manufacturing cost	Down 22%	Down 19%	×
Production volume	Up 66%	Up 64%	△

Possible causes of failing to achieve the targets are:

[1] Higher manufacturing cost due to lower availability

A major cause of lower availability was that work waiting for finishing had to be temporarily placed at the point where several types of work join after the FMS area. To improve the situation, we plan to install shelves for work waiting for finishing. This improvement is expected to help achieve the target.

[2] Deviation from the initial production plan

The reason for failing to achieve the target production volume was that the initial production plan for the target month for evaluation was not achieved. Still, the target production capacity was achieved.

8 Conclusions

We have successfully implemented stable preventive maintenance using a new measurement method, thereby establishing a product satisfying the process capability which was conventionally difficult to achieve. From now on, we will carry out activities that can develop preventive maintenance into predictive maintenance based on accumulated data and will also continuously improve the availability whose target has not yet been achieved.

9 In Closing

Finally, I would like to take this opportunity to express my appreciation to the related functions that extended cooperation in building the production line as well as those who extended guidance and support to us.

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