Sintered Parts Production Line Using IoT Technology

Naoto IGARASHI*, Masanobu TAKAGI, Kiyoshi TAKAHASHI, Hiroaki TERAI, Ryuta SAWADA, and Shogo SAKAGUCHI

Due to technological innovation utilizing information technology (the fourth industrial revolution), major changes are taking place at manufacturing sites. Internet of Things (IoT) technology is expected to improve production capacity and efficiency through the collection and analysis of a large amount of data by networking many sensors and devices. In the automobile industry, the development of common platforms and modules has been progressing, requiring parts manufacturers to cope with demands for cost reduction in super-mass production and quality risk management to prevent mega recall. To adapt to the age of mega-platforms, we have built an innovative sintered part production line making full use of IoT technology. Based on the Sumitomo Electric Group's manufacturing concept, Sumitomo Electric Industries Production System (SEIPS), the new production line features: (1) zoned quality control by automated inspections, (2) quality assurance in units of products using 2D codes, (3) reduction of lead time and no intermediate stock by "one-by-one production / synchronized production" through compacting, sintering, sizing, to machining, and (4) IT-based production-management and monitoring systems.

Keywords: IoT, one-piece-flow manufacturing, zoned quality control, variable valve timing

1. Introduction

Technological innovation utilizing information technology, known as the Fourth Industrial Revolution,*[1] is bringing major changes into production frontlines. In particular, Internet of Things (IoT)*[2] technology is the focus of expectations as a new value creator for the possibilities it offers to improve production capabilities and efficiency through gathering and analyzing large volumes of data from a number of networked sensors and devices.

The Sumitomo Electric Group has established the Sumitomo Electric Industries Production System (SEIPS)*[3] as a group-wide manufacturing principle in order to continuously deliver value to customers through constant improvement of Compliance, Speed, and Value, based on first-in-first-out (FIFO) production flow (Fig. 1). The Group is also stepping ahead in utilizing IoT technology, including the following examples: (1) real-time monitoring of production status by efficiently gathering and visualizing factory production system information, such as facilities in operation, production data, and manual work data; (2) early detection of facility failures and shortening of downtime by viewing accumulated past data; and (3) ongoing installation of the SEIPS-IT system for quality improvement based on production conditions and product inspections (Fig. 2).

Production streamlining has been carried out in the car industry in recent years, including development time reduction through universal standardization of car components. This is achieved by utilization of a car platform together with modularization and brings the benefits of drastic cost reduction through economies of scale brought about by such universal standardization. At the same time, universal standardization can result in an unprecedented scale of quality failures, such as a mega-recall with more than a million cars needing to be retrieved. Against this backdrop, it is an imminent issue to build a production system and a quality assurance (QA) system appropriate to such changes in the car component industry.

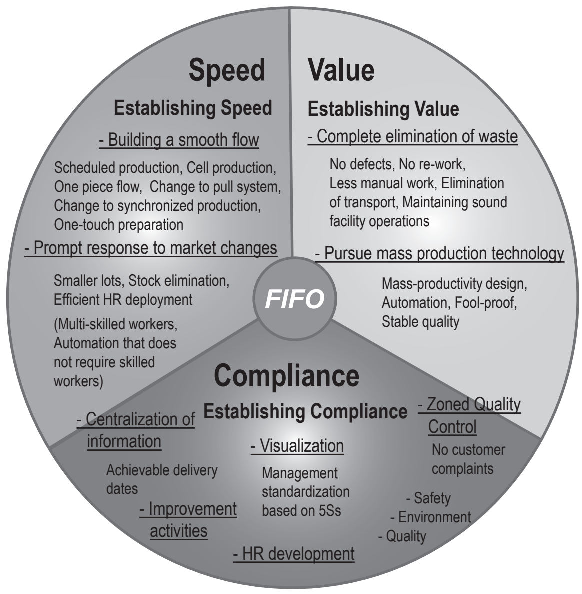

Fig. 1. SEIPS (SEI production system) principle

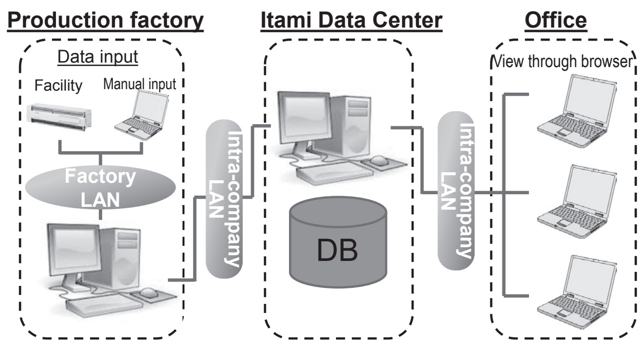

Fig. 2. Overview of SEIPS-IT system

We have now built an innovative production line of sintered parts that employs production and QA methods that suit this era of mega-platforms (Fig. 3). This production line adopts the SEIPS production approach in combination with IoT technology that covers (1) zoned quality control by automated inspections; (2) quality assurance per product piece using a unique 2D code;*4,[1] (3) drastic lead time reduction and intermediate stock elimination by one-piece-flow manufacturing and synchronized production that run through compacting, sintering, sizing, and machining as a single procedure; and (4) production management and monitoring systems that utilize IT.

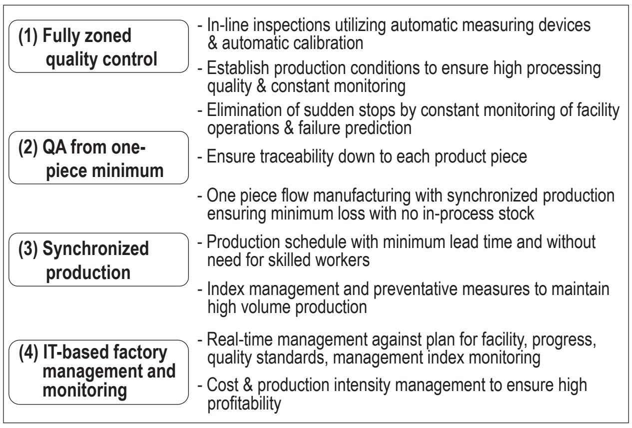

Fig. 3. Production line design

2. Smart Production Line of Sintered Parts

The sintered parts manufactured in this production line are parts used in a variable valve timing (VVT) system. The VVT system is used to improve fuel efficiency and reduce exhaust emissions by changing the opening and closing timings of the intake and exhaust valves, the timings of which are generally fixed. Now this system is increasingly being installed in car engines (Fig. 4).

VVT systems can be divided into oil control types and electric control types. Currently, the oil control VVT system is in wide use as it uses less components and can be produced at a more reasonable cost. However, the electric control VVT system is expected to become the mainstream in the near future to comply with progressively stricter emission regulations. This is because the system is better at phase control in terms of a wider operable phase range and better response, as well as its capability of being fully functional at engine startup and at low temperatures, when the oil control type is slow.[2],[3] Still, there is a challenge of cost reduction for the electric control VVT system to become widespread as its unit cost is expensive due to the necessity of a driving motor and a reduction gear, which are not required in an oil control VVT system. Therefore, it is necessary to make significant cost reductions through large-scale universal standardization of components for the cycloid reduction gear, the major component of our electric control VVT system.

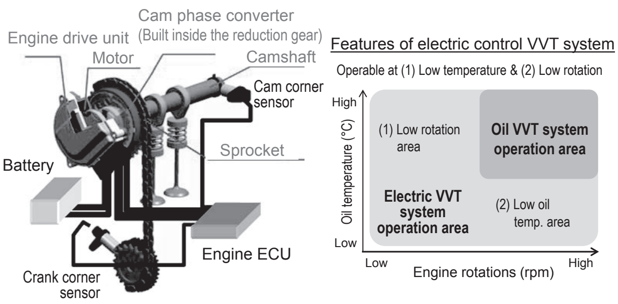

Fig. 4. Electric control VVT system overview[2], [3]

The components we developed at this time were the major components for the cycloid reduction gear, including a camshaft gear, planetary gear, and sprocket gear (Fig. 5).

Fig. 5. Appearance of developed products

The major characteristics commonly required in these components are (1) highly precise tooth profile to reduce noise and vibration during gear engagement; and (2) tooth hardness and mechanical strength to transmit high torque. Each component is heat treated (hardening and tempering) to ensure tooth hardness and mechanical strength (Fig. 6). However, generally speaking, components can be deformed by heat treatment and dimensional precision compromised. Thus, it is technically important to minimize deterioration in dimensional precision by heat treatment.

The sintered part production line we have developed can achieve high tooth profile precision, tooth surface

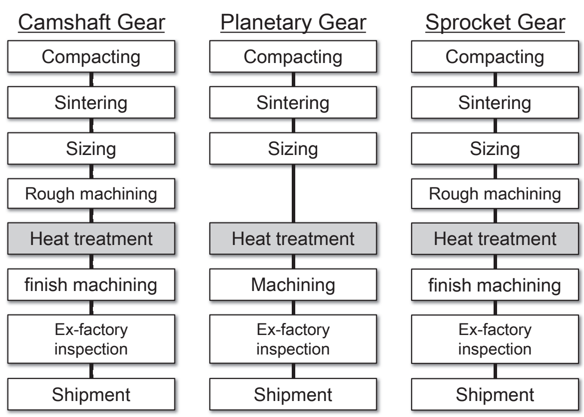

Fig. 6. Developed production process

hardness, and mechanical strength at the same time by enhancing monitoring and controlling capabilities through zoned quality control using IoT technology (described later), along with optimizing conditions of each production process by big data analysis.

Features of the developed production line of sintered parts are described below.

2-1 Zoned quality control

To achieve the precision level of tooth profile required in this development, it was necessary to manage production conditions and ensure quality in each process—from compacting to heat treatment—at a much higher standard than conventionally required for sintered part production. Up to now, by painstakingly the accumulating strict quality control measure on each production process, we could barely match the minimum quality level required by customer. In the newly developed production line, we installed an inspection machine in the facility of each process enabling us to conduct in-line inspections for every product item in each process. This enhanced the control and monitoring capability for each production process, ensuring the strict dimensional precision requirements set in each process were met in order to achieve the extremely accurate tooth profiles required in the final product.

2-2 Quality assurance for each product piece

Sintered parts made through this newly developed production line are engraved with a 2D code during the compacting process in order that individual pieces can be identified. As the piece moves through each production process, this engraved 2D code is read and recorded along with the production conditions of that process.

This production record includes the date and time when the piece passed through each process and production conditions (press operation diagram, bottom dead center, sintering temperature chart, etc.). This is then linked with information on the product after it completes the process (zoned quality assurance information: weight, dimensions, inspected images, inspection results, etc.), and this entire set of information is then stored in a server as big data (Fig. 7).

The above big data can be utilized in the following ways. For example, quality defects can be quickly resolved by reading the 2D code engraved in the defective product as this instantly displays the product information and production conditions when it was made. It is also possible to analyze a large data set of product information and production conditions to immediately determine the factors influencing production, such as "dimension changes of products in different production processes" and "correlations between product dimension changes and production position within the heat treatment furnace." Such analysis can help conduct highly precise factor analysis of the production conditions that affect the product. Analyzing big data may also discover new correlations that could not be identified from conventional small data sets, and such correlations can be formulated or quantified.

Knowledge gained in the manner described above can be utilized to optimize the production conditions, and we can then make the procedure into a cycle of production line improvements, verification of these improvements through further big data analysis, and reflection of the verification results in making future advancements.

Implementing this cycle of constant evolution into the developed production line transformed it into a smart production line for sintered parts.

2-3 One-piece-flow manufacturing and synchronized production

Reduction in production lead time and stock control become even more important in mega-modularized mass production in order to respond to finely tuned orders from customers, by producing only the pieces required, in the required quantities, and at the required times.

One-piece-flow manufacturing was realized in the developed production line by combining the conventionally separate production processes of compacting, sintering, sizing, and machining into one procedure utilizing a self-built conveyor line. Adoption of one-piece-flow manufacturing

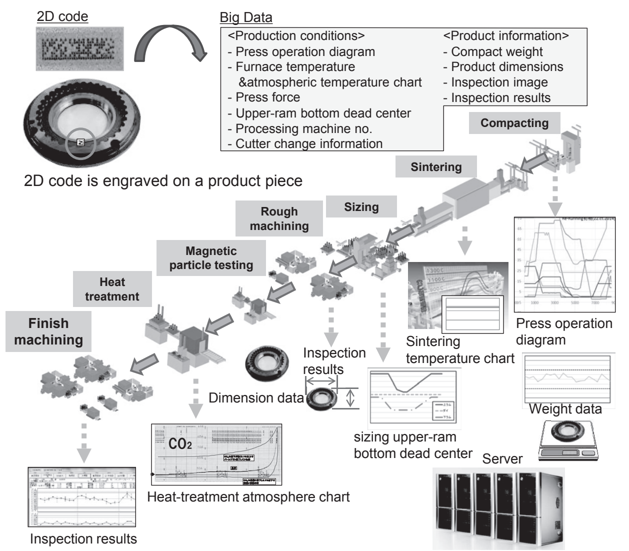

Fig. 7. Overview of zoned quality assurance and quality assurance per product piece

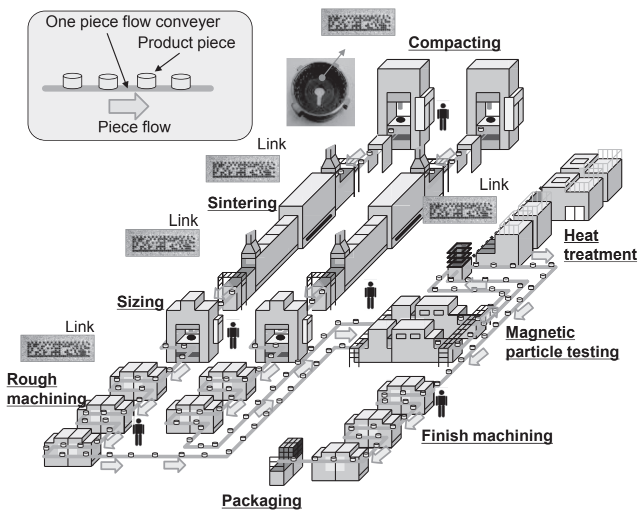

Fig. 8. Outline of fully automated one piece flow manufacturing

and inter-process synchronized production in the developed line also provides the following benefits: (1) significant reduction in lead time (1/10 the conventional lead time and 1/4 the preparation time); (2) elimination of intermediate stock between processes; (3) realization of full FIFO; and (4) minimization of product defects by quality assurance per product piece by zoned quality control in each process (Fig. 8).

Also, the production line with one-piece-flow manufacturing and synchronized production eliminates the waiting time between processes, realizing more efficient facility operations. This in turn brought the following advantages: (5) improvement in overall operation efficiency of the facilities; (6) energy conservation and elimination of manual work, including conveying product pieces from one process to another; and (7) significant reduction in human resource costs.

2-4 Factory management and monitoring system utilizing IT

To maintain high volume production and high quality, it is necessary to promptly and efficiently improve product quality and facility operation rates by keeping up with the indices of Quality, Cost, Delivery time (QCD) in a timely manner. For this reason, we gather and visualize various types of information generated at different stages of the production frontline by using the aforementioned SEIPS-IT technology. We have so far established the following indices to maintain and control QCD: (1) quality index: keeping up with changes in key management factors and results; (2) cost index: facility operation rates, production progress against the production plan, and cost & production intensity management; and (3) delivery time index: real-time management of planned and actual in-process inventory (Fig. 9).

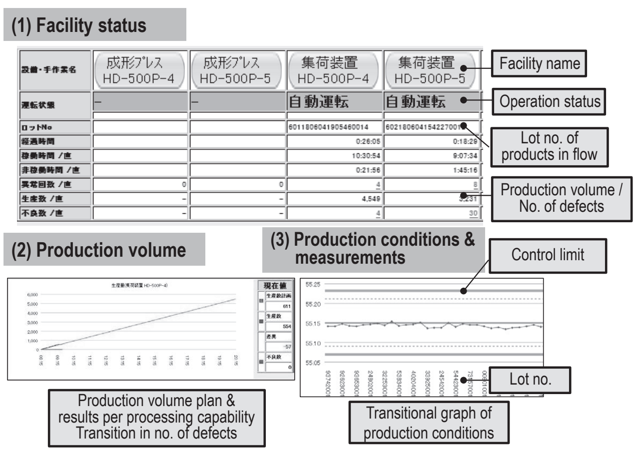

Fig. 9. Sample of real-time display of QCD index

3. Conclusion

We built an innovative production line for sintered parts that employs the production and QA methods appropriate to the era of mega-modularization. This production line adopted the SEIPS production approach combined with IoT technology that covers (1) zoned quality control by automated inspections; (2) quality assurance per product piece using a 2D code; (3) drastic lead time reduction and intermediate stock elimination by one-piece-flow manufacturing and synchronized production that runs through compacting, sintering, sizing, and machining as a single procedure; (4) a production management and monitoring system that exploits IT. This production line has been in operation since November 2016, producing 500,000 sintered parts per month for electric control VVT systems, reaching a total of 3.3 million parts as of May 2018.

Technical Terms

*1 The Fourth Industrial Revolution (Industry 4.0): The high-tech strategy of the German government to promote the digitization and computerization of manufacturing, which commenced in 2011. A revolutionary change in the manufacturing industry utilizing IoT technology and AI.

*2 Internet of Things (IoT): An inter-controllable mechanism for devices connected to the Internet that functions by exchanging various data items.

*3 Sumitomo Electric Industries Production System (SEIPS): The manufacturing principle aimed at by the Sumitomo Electric Group.

*4 2D code: A two-dimensional code. A barcode that contains information in both horizontal and vertical directions unlike a conventional barcode that holds information in the horizontal direction only. The 2D code can, therefore, hold more information and this in turn can reduce the code printing area.

References

(1) Naoto IGARASHI et al, "High-Quality High-Productivity Manufacturing of Variable Valve Timing Parts by Green Machining," SEI Technical Review, No. 85 (2017)

(2) Akihiko TAKENAKA, Motor Ring No. 28 (2009)

(3) Akihiko TAKENAKA et al, "Development of a Variable Valve Timing System Controlled by an Electric Motor," DENSO Technical Review Vol. 14, pp.24-29 (2009)

Contributors
The lead author is indicated by an asterisk (*).

N. IGARASHI*


• Group Manager, Sumitomo Electric Sintered Alloy, Ltd.

M. TAKAGI


• Senior Assistant General Manager, Sales Department

K. TAKAHASHI


• Assistant Manager, Sumitomo Electric Sintered Alloy, Ltd.

H. TERAI


• Plant Manager, Sumitomo Electric Sintered Alloy, Ltd.

R. SAWADA


• Information Systems Division

S. SAKAGUCHI


• Plant & Production Systems Engineering Division