IoE Initiatives

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Industry is facing the problem of worsening labor shortages on the production shop floor due to factors such as a decline in the working population and shortage of successors to seasoned technicians. Meanwhile, there are increasingly high expectations that rapidly-advancing IT technologies and utilization of information such as big data, learning and AI will dramatically solve such problems affecting monozukuri and bring about a paradigm shift in the manufacturing industry. This paper will report on JTEKT's IoE (Internet of Everything) activities and our initiatives for solving monozukuri issues which we intend on reflecting in future activities.

***Key Words**: IoT, AI, IoE, smart factory, line builder*

1. Introduction

In recent years, advancements in information technology such as IoT (Internet of Things), big data and AI have aroused expectations that there will be major changes to the fundamental way we work and live. Moreover, in the industrial sector, such technological advancements have been referred to as triggers of a fourth industrial revolution, and studies for their utilization in various fields have been ongoing since around 2011. In Japan, there are many manufacturers who obtain data from systems and production equipment, however there are reports that such data is not being properly analyzed[1)] in some cases, therefore there is an urgent need to build smart factories in which all elements of a factory are connected via a computer network (**Fig. 1**).

Believing these to be important technologies that will transform monozukuri, JTEKT has conducted investigations and utilized consulting and group venture companies since 2012 to promote IoE (Internet of Everything – term coined by JTEKT) so that we may use it to further grow our Machine Tools & Mechatronics business. In contrast to IoT, IoE is a concept clarified by JTEKT which expresses the connection between "things" to "everything" (people, information, etc.), based on our belief that we could also incorporate information on the people who work in factories to unlock the potential of peoples' roles (**Fig. 2**).

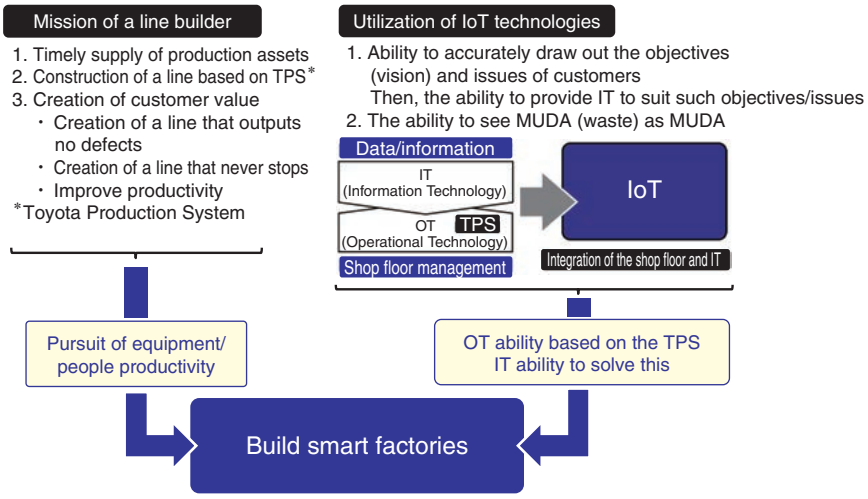


Fig. 1 Smart factory

Fig. 2 The IoE concept

2. Strategies of Various Countries

The growing trend to evolve factories into 'smart factories' leveraging IoT technologies, etc. has to some extent been driven by national-level strategies. With the aim of stimulating new growth in the monozukuri field and creating change in terms of industrial composition and product configuration, initiatives are being led by national governments and through a top-down approach with the involvement of influential corporations.

Meanwhile, IT technologies have widely spread throughout common society and there is a growing bottom-up trend whereby proposals for new technologies aimed at achieving smart factories originate from a wider range of sources, including venture companies.

2. 1 Industry 4.0

Industry 4.0 was announced in 2012 as Germany's new national strategy for economic growth and its essence is the construction of a cyber-physical* industrial society through digitalization and computerization. Concrete manifestations of Industry 4.0 have been presented as process improvement and better traceability in production, the transfer of consumption information enabling immediate response to the individual needs of consumers, and the realization of mass customization.

* This refers to a service of making events conventionally reliant on "experience and intuition" more efficient in order to realize a highly-advanced society

2. 2 IIC (Industrial Internet Consortium)

In the U.S., many companies participate in the IIC. General Electric Company (GE), International Business Machines Corporation (IBM), Cisco System, Inc. (CISCO), AT & T Inc. and Intel Corporation are the main pioneers providing participating corporations with verification environments targeting a wider scope encompassing Industry 4.0. At this point of time, no established regulations and standards exist, and technological advancements by IIC are setting precedent.

2. 3 Connected Industries

In Japan, the strategy is "Connected Industries" announced by the Ministry of Economy, Trade and Industry (METI). As **Fig. 3** shows, the basic concept of Connected Industries comprises three main elements. An industrial society where people play active roles is being incorporated in the ideology and is consistent with the IoE promoted by JTEKT.

Basic concept

Industrial society in which new added values are created through various connections.

Amidst advancing digitalization, leverage Japan's strengths of high "technological capability" and sophisticated "shop floor capability in an attempt to build a new, solution-orientated industrial society.

Create a people-centered industrial society in which case-by-case problem-solving ability, ongoing improvement activities, etc. backed by thorough shop floor knowledge can be leveraged.

Three main elements

1. Realize a new digital society in which people, machines and systems do not oppose one another, but rather collaborate together
2. Problem solution through cooperation and collaboration
3. Adhering to a "people-focused" approach, proactively promote development of professionals in line with advancements in digital technology

Source: METI press release
http://www.meti.go.jp/press/2016/03/20170320001/20170320001.html

Fig. 3 Connected industries

3. Status of Various Companies Observed at the 2018 Hannover Messe

JTEKT had the opportunity to exhibit at the Hannover Messe held in Germany in April 2018 and took advantage of this to investigate the status of various companies' initiatives relating to IoT technologies and Industry 4.0. Both in Japan and abroad, there are more and more cases of IT companies approaching the "edge layer" (equipment/factory side) and multiple manufacturers must liaise with one another.

3. 1 Manufacturer Trends

Industry-leader, Siemens AG, was emphasizing that now is not the time to contemplate the concept of Industry 4.0, but rather to realize it. As such, there is growing awareness of practical application in actual production sites.

There is an impression that major IT companies have begun approaching areas closer to the edge layer, however this cannot be achieved by one company in isolation, therefore the mainstream approach is to form consortiums comprising platform providers and platform users (**Fig. 4**).

This is the case not only in Europe, but also in Japan, where there is much activity surrounding the FIELD System by Fanuc Corporation, and Edgecross, which was established by six companies including Mitsubishi Electric and Omron (**Fig. 5**).

3. 2 IoT & AI

Regarding IoT, the term itself was less visible, possibly due to the spread of the concept, and there was an AI-centered shift towards robot advancements and unmanned operation. There were many robots on display at the 2018 Hannover Messe overall, giving the impression of a weakened focus on people. Advancements are being made in the AI-controlled 2-arm robot (**Fig. 6**) and table tennis robot, with the mainstream theme of exhibits being cobots able to work together with humans on manufacturing shop floors.

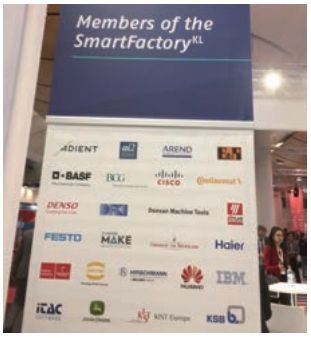


Fig. 4 Cooperative companies 1

Fig. 5 Cooperative companies 2

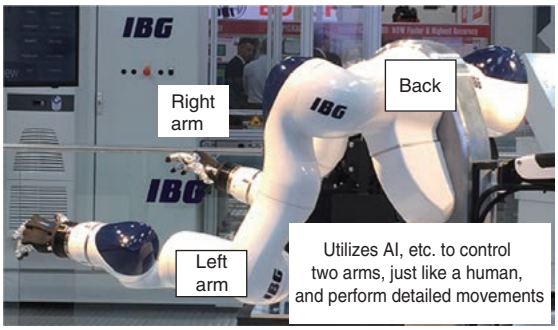


Fig. 6 Two-arm robot

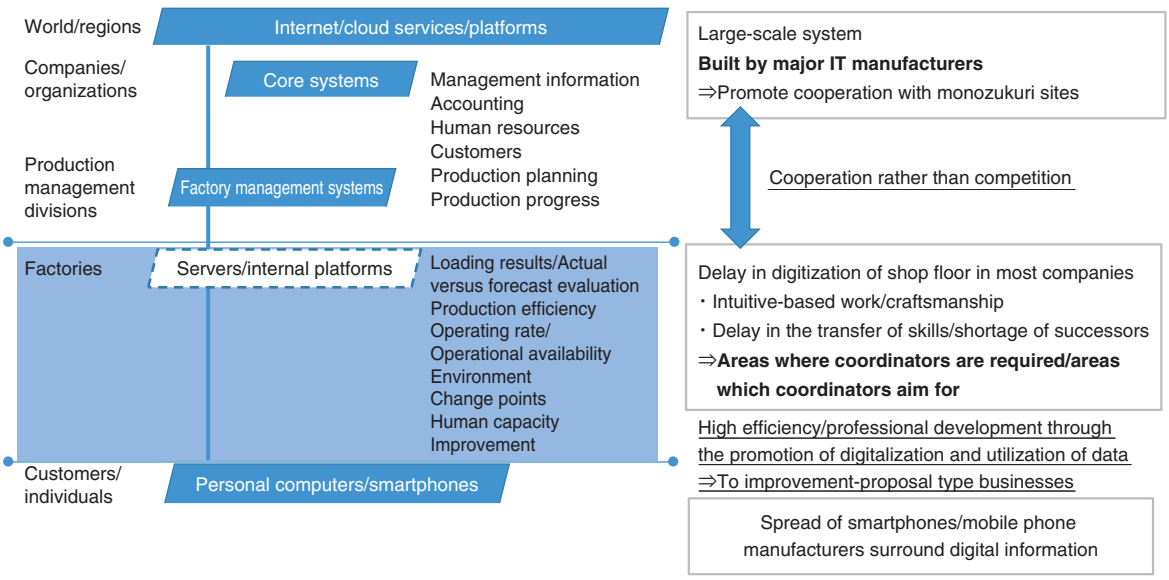


Fig. 7 Positioning of factories

4. Activities of Service Providers/Service Users and JTEKT

The trends discussed in **Section 3** are also the case within Japan, and many companies from across the spectrum are already engaging in initiatives to realize the digitalization proposed by Industry 4.0 and IIC. On one end of the spectrum, major IT and NC manufacturers are injecting cloud services and platforms, and adding to areas up to deployment to the edge layer.

On the other hand, digitalization in the edge layer is behind overall. Production shop floors seek more realistic results and do not recklessly promote digitalization, therefore often take a "wait-and-see" stance. Cases have been emerging whereby major manufacturers first collect data then proceed with initiatives while performing learning and analyses, however small-and-medium manufacturers are unable to allocate dedicated personnel to such a task, therefore no progress is made.

On the factory side, there is a lack of a function to coordinate digitalization and it is up to line builders such as JTEKT to gather strength.

From our position of providing equipment and systems, JTEKT is engaging in an ongoing activity to digitalize production information in factories and gather use cases in which production has been improved as a result in order to not only create equipment and systems, but also added value for JTEKT. The key phrase of this initiative is "smart factories in which people play a leading role."

Factories must address the urgent issues of dealing with a declining working population and passing on craftsmanship. While handling these issues, JTEKT is helping form a vision for the higher efficiency of factories and the people who work in them.

5. IoE Initiatives and the Technologies Thereof

5. 1 Smartification of Machines

Manufacturers are aiming to develop production equipment with more advanced autonomy, or in other words, "smartification." In reality, up until now, the maintenance of equipment operability, assurance of machining accuracy and quality have been achieved at a high standard due to human skill. However, we envision a future where these things will be achieved at a high standard by equipment becoming autonomous through utilization of IoE, etc.

5. 1. 1 Symptom Management

Emphasis is placed on the management of equipment condition and planned maintenance in order to prevent production stoppages due to sudden breakdowns. Seasoned veterans are able to sense problems in equipment from subtle sounds, vibrations, machining results and so on, however it is not possible to incorporate human judgment such as this in more automated production lines, therefore sudden breakdowns do occur. Moreover, there is a rapid decrease in the number of seasoned workers able to sense problems in equipment.

If equipment behavior is digitalized using sensors, etc. and equipment is able to learn combining equipment behavior, breakdown information and machining quality information, it is possible to establish symptom management not reliant on human senses. JTEKT's IoE initiatives have also resulted in acquiring knowledge leading to preventive maintenance through analysis. Below are some examples of these.

①Detection of grinding chatter symptoms (**Fig. 8**)
②Detection of grinding seizure symptoms (**Fig. 9**)
③Detection of spindle bearing abnormalities (**Fig. 10**)
④Prediction of drill/end mill tool life (**Fig. 11**)

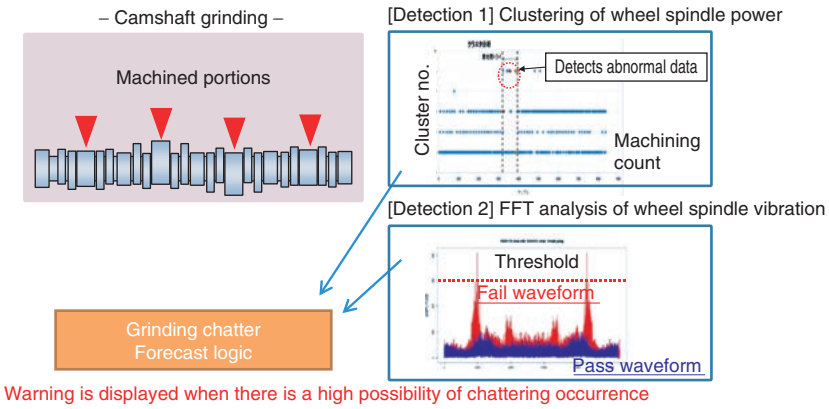


Fig. 8 Chattering judgment for camshaft grinding

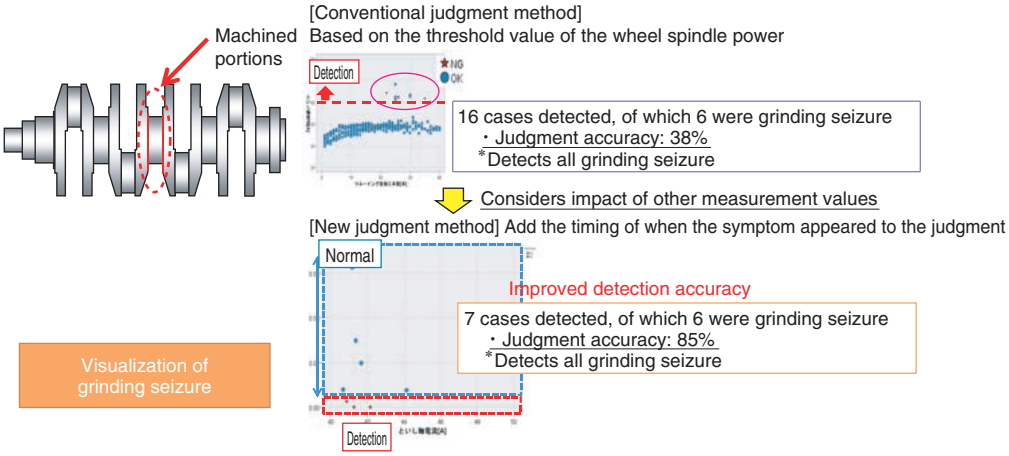


Fig. 9 Seizure judgment for end-face grinding

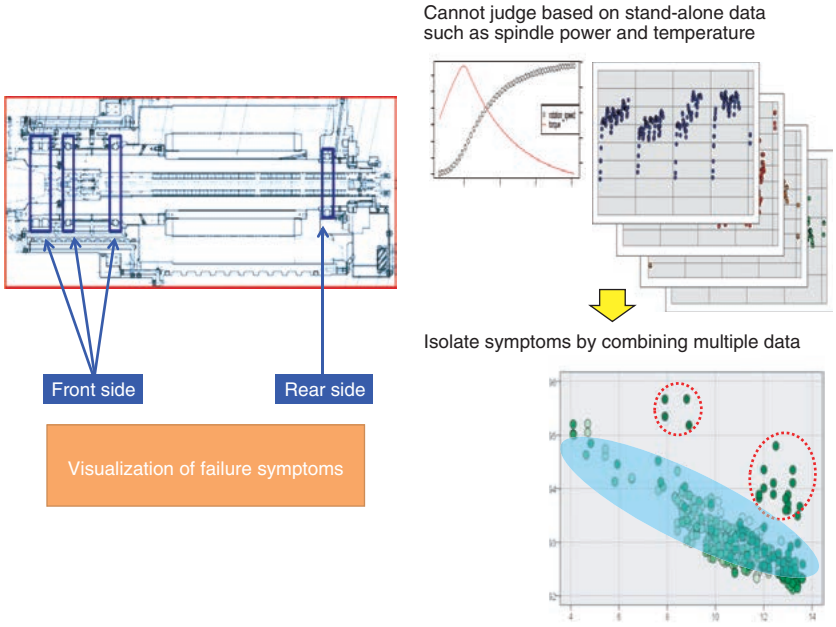
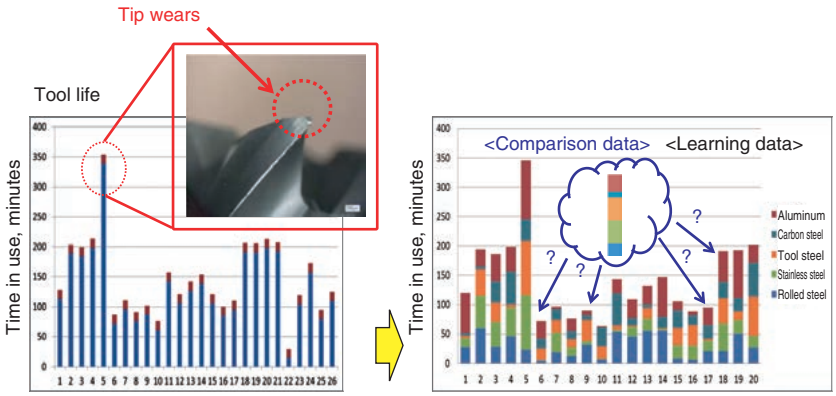


Fig. 10 Symptoms of main spindle bearing failure



・On high-mix machining lines, the same tool machines parts of different material, therefore tool life varies.
・The appropriate timing for tool replacement cannot be predicted from conventional tool operating time.

Learns patterns and gives tool replacement instructions with greater accuracy
・Learns patterns of material differences
・Recognizes which patterns are similar before machining and predicts life from similar pattern

Fig. 11 Forecast of tool life for drills/end mills

5. 1. 2 JTEKT Smart Cutting

In the cutting process, selection of machining conditions is an important point in order to achieve a high-quality machined surface free of chatter marks. To date, operators would observe the conditions of the machine, repeatedly carry out trial machining based on their experience and, ultimately, settle on machining conditions.

However, such an approach requires a great deal of preparation time, and some ambiguity remains regarding whether or not the machining conditions are optimal, with regards to productivity as well. The JTEKT Smart Cutting function featured on JTEKT's machining centers digitally present the optimal machining conditions for stable accuracy by easily acquiring vibration characteristics of the spindle system, including tools, and analyzing data in line with machining phenomena.

5. 1. 3 Real-time Thermal Displacement Correction

The thermal displacement of machine tools has been a longstanding issue in mechanical machining. Temperature changes in the equipment's environment and heat generated by the machine itself causes the machine to distort overall, and deteriorates machining accuracy. As such, we measured the machine body's temperature using multiple sensors embedded in the machine, analyzed heat distortion in real-time and enabled the calculation of the suitable correction amount.

In JTEKT's thermal displacement analysis logic, the FEM analysis method which conventionally required several hours to complete can be performed in mere seconds, thus allowing correction to be carried out in real-time during machining. This is a technology that is pioneering IoE activities by digitally connecting equipment information and machining quality.

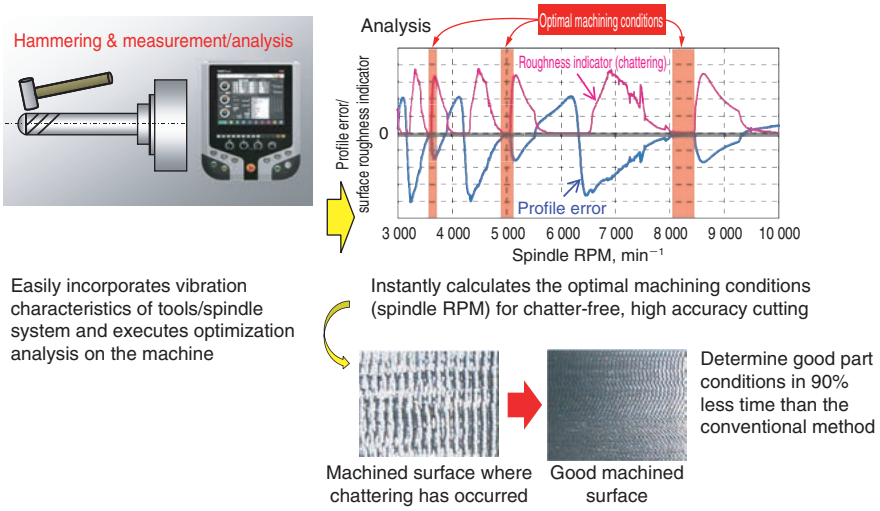


Fig. 12 JTEKT smart cutting

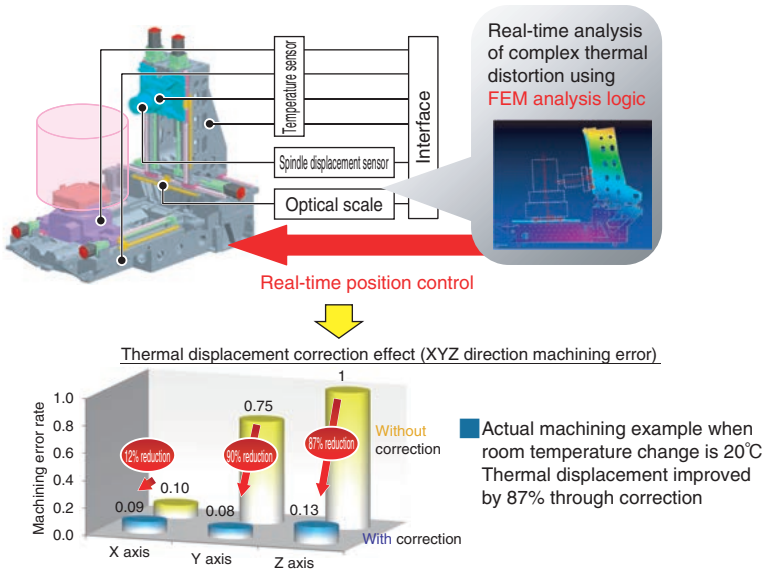


Fig. 13 Real-time thermal displacement correction

5. 2 Visualization of Production

In order to improve productivity, JTEKT is promoting an initiative to vitalize production shop floor improvements through visualization of actual vs. forecast production results in relation to the production plan. To date, automotive production lines, etc. have used the andon system, whereby indicators such as production quantity, equipment operating rate and abnormal stoppages are displayed in real-time on andons so that supervisors can immediately take the necessary response. The andon system is advancing while establishing the necessary visualization requirements in line with advancements in TPS.

As part of our IoE initiatives, JTEKT is rolling out TOYOPUC-Hawkeye as a universal andon system that enables operational status for not only automotive production lines but also the general-purpose machines of FMCs (flexible manufacturing cells), and multiple equipment.

To give an example, one or two operators are in charge of eight machining centers, however each machine performs high-mix, small-volume machining, therefore machining time varies. The operators load the next workpiece into the loading station in line with machining progress and operate eight machines, however in reality there is wait time as the operators travel back and forth each time machining ends.

Here, we introduced TOYOPUC-Hawkeye for the visualization of remaining machining time, the part number of the next workpiece required, and the loading status. The process was improved so that operators could make preparations prior to the end of machining, thus greatly improving productivity.

Fig. 14 TOYOPUC-Hawkeye

Moreover, as a simple method of achieving visualization of equipment operational status, JTEKT released JTEKT-SignalHop, a solution that reads and records the color of status indicator lamps. The respective colors of a status indicator lamp already have set meanings, such as “in operation,” “stopped,” and “fault,” therefore visualization of equipment operational status can be easily achieved by simply recording these colors (**Fig. 14**).

JTEKT-SignalHop performs communication wirelessly, and can be mounted with tape. The power source is a built-in battery, therefore electric wires are not required. The transmitter attached to the top of the status indicator lamp transmits illumination information to receivers fixed in an arbitrary position inside the factory, which is then recorded. One receiver can support up to 50 transmitters (**Fig. 15**).

The collected illumination information is used to list up machine operational information such as which equipment has performed what amount of machining,

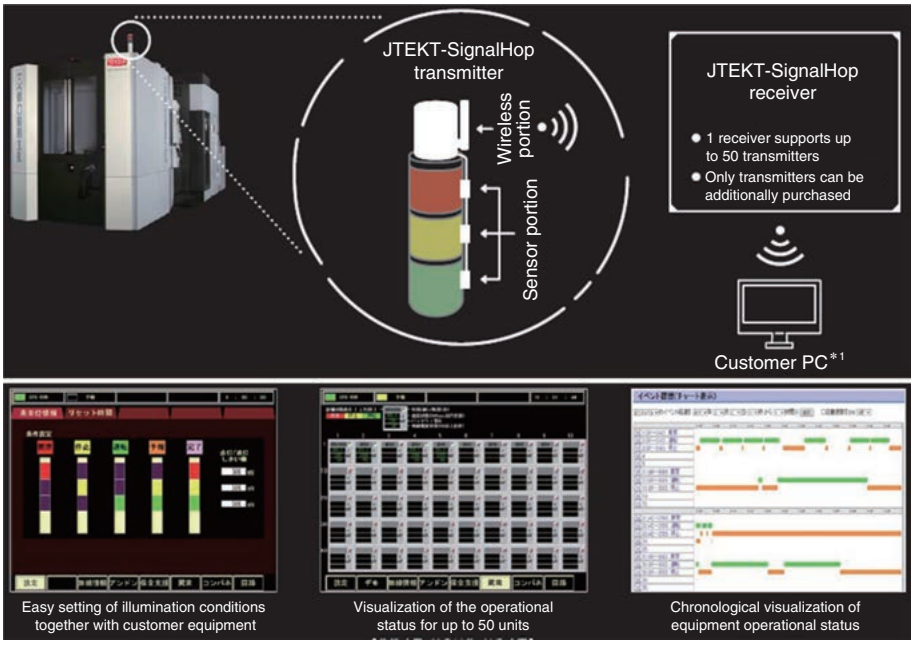


Fig. 15 JTEKT-SignalHop

which equipment is stopped, and whether or not there were any faults. As such, in the same way as TOYOPUC-Hawkeye, JTEKT-SignalHop enables production status to be easily ascertained so that areas for improvement can be narrowed down. Customers who have actually introduced these products to their lines are benefiting by utilizing information through creating their own original screens, etc. and leveraging information to improve time wastage.

6. Conclusion

JTEKT is already facing the issues of a declining working population, shortage of skilled labor, and delay in the transfer of craftsmanship.

While a significant part of the territory relies on advancements in IT technology and digitalization, it is JTEKT's major mission in our role as a line builder to do what we can to transform the monozukuri shop floor.

Currently, for our IoE initiative, we are pushing ahead with visualization and digitalization of production status both internally and externally and contributing to improvements in production and quality while trying to establish it as a business, however we believe we still have a long way to go insofar as accumulating use cases on the shop floor. If each of our activities can be converted into solutions solving our customers' true problems than they will surely become essential to monozukuri in the future, so JTEKT will keep firmly focused on this task and continue exerting effort in this area.

*1 TOYOPUC-Hawkeye and JTEKT-SignalHop are registered trademarks of JTEKT Corporation.
*2 FIELD System is a registered trademark of FANUC Corporation.
*3 Edgecross is a registered trademark of Mitsubishi Electric Corporation.

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