PRODUCTION TECHNOLOGY AND PRODUCTION SYSTEMS

1 Introduction

In 2017 the global automobile market exceeded 90 million vehicles for the second consecutive year following the continued growth in China and India, and the bottoming out of the markets in Brazil and Russia. The Japanese market also fared well, with reaching more than 5 million vehicles for the first time in two years thanks to the economic recovery. However, sales are slowing in the U.S. and China, making future economic conditions unpredictable.

At the same time, automotive market demand for environmentally-friendly technologies and safety technologies is rising, and weight reduction, electric motorization, automated driving technologies, and connected vehicles are anticipated to become mainstream within the next ten years.

Production technology must not only contend with those needs, but also respond to the rise in the production ratio outside Japan and the risk posed by the decrease in the Japanese labor force. It is critically important to maintain *monozukuri* (Japanese manufacturing) competitiveness in the face of emerging nations that have been making rapid improvements inter terms of costs and level of quality.

Therefore, beyond new materials and innovative manufacturing methods, the development of a production system that applies various technologies, including the Internet of things (IoT) and artificial intelligence (AI), is expected to improve both productivity and quality.

2 Vehicle Production Engineering (PE) Technologies

2. 1. Stamping

In addition to social demand for safer, more environmentally-friendly vehicles, there is also growing demand to develop new technologies such as electric motorization and automated driving and create more appealing vehicle designs. In the field of stamping technologies there are growing calls for more efficient use of materials without creating waste and the capability to faithfully create the body shape required by the designers. Moreover, weight reduction concerns are making it urgent to improve forming and shaping technologies for aluminum alloy materials and high-strength steel sheets. At the same time, rising demand for better panel quality is driving efforts to apply IoT to refine on-site quality.

In the field of automotive design, a mold structure-formability coupled analysis that accounts for metal mold deflection is now conducted on conventional panels as a single unit during the analysis stage, gradually making it possible to form heretofore unachievable character lines with sharp-edge structures and complicated shapes.

Recent efforts to further reduce the weight of vehicles and parts have embraced the full-scale adoption of multi-material structures that use aluminum alloys and other materials, in addition to high-strength steel sheets that exceed 1,200 MPa, under the philosophy of applying the right material to the right place. In particular, aluminum is 65% lighter than steel and consequently increasingly used in cover parts, such as tail gates and hoods. However, aluminum is a difficult material to form due to its low elongation percentage and tendency to crack during drawing and bending. In addition, the trimming process produces chips, and numerous appearance defects are also an issue. Further improvements to simulation technologies and efforts to advance surface treatment technologies are being undertaken to solve these problems.

Until now work management and quality assurance processes at production sites centered on the five human senses, but recent advances in IoT have enabled real time monitoring of additional information from workers, as well as changes in equipment, molds, and materials. Big data is also increasingly being leveraged for on-site improvement and control over the factors that influence quality. Quality control for panel quality assurance often relied on the eyes of skilled workers, but is now moving toward automatic visual inspection of the appearance using camera recognition technology. Furthermore, the accumulation and analysis of product quality information and production information collected from the equipment is expected to result in management that will stabilize overall quality. To this end, efforts are being made to digitize the record taking conventionally done on paper, and to develop technologies for installing sensors that constantly monitor production facilities. Data gathered from the facilities in real time is also expected to contribute to improving the capacity utilization rate by, for example, identifying signs of potential failures in advance.

Japan's aging society and falling birthrate are focusing attention on creating safe working environments that are friendly to production workers, and the need to automate work conventionally performed by people is growing. Consequently, unmanned transportation of parts by an automated guided vehicle (AGV) and the use of robots for simple tasks is becoming more common, and it is expected that robots capable of performing work comparable to that of people via a camera system and AI will eventually be developed.

2. 2. Welding

Initiatives to reduce weight while increasing rigidity have been undertaken to allow automobile bodies to meet the growing demand for lower CO_2 emissions, better fuel economy, greater safety, and good maneuverability. This is compounded by the weight increase due to the installation of electronic and control equipment on next-generation vehicles, prompting calls to further reduce the weight of the car body. To achieve this, automobile manufacturers have expanded their use of lighter weight replacement materials, and have consequently also had to develop and commercialize a variety of new joining and bonding methods.

Examples of these lightweight materials include high tensile strength steel sheets (high-strength steel), aluminum alloys (aluminum), plastics, and composite materials made from plastic and carbon fiber (CFRPs). Increased use of 1,200-MPa class ultra-high-strength steel and aluminum alloys has led to the adoption of hot stamping materials with even higher strength than ultra-high-strength steel, as well as aluminum extrusion materials and castings. Plastic materials are often applied to outer panels and cover parts, with some high-end luxury vehicles even using CFRPs for this purpose.

When spot welding ultra-high-strength steel, it is difficult to generate the nugget and ensure the strength of the welded portion because the electric resistance is different from that of mild steel sheets, the carbon content is higher, and springback is liable to cause a gap. These drawbacks are being addressed through advanced control over pressure and electric current conditions at the time of welding. The stronger the steel sheet, the more difficult it becomes to check the quality of a spot weld using a destructive chisel test. Consequently, a non-destructive inspection apparatus that uses ultrasonic waves and magnetism is being introduced.

Spot welding two pieces of aluminum together has been considered difficult since that material has lower electric resistance and higher thermal conductivity than steel. However, the ability to use high pressures and electric currents has been expanding the applicable scope of this technique. The strong desire to apply aluminum to the vehicle frame has made the adoption of self-piercing riveting (SPR) increasingly common as a technology to join aluminum and steel.

Conventional rivets and bolts are often used to join plastic, and the joining plastic using only adhesives is also used.

Continuous joining is an effective means of increasing the rigidity of the vehicle and the application of adhesives for this purpose is continuing to expand.

As a multi-material approach becomes more common, various joining and bonding methods, such as SPR, friction stir welding (FSW), Flow Drill Screw (FDS), TOX, blind riveting, lasers, ultrasonic waves, electromagnetic waves, arc welding, and brazing are being developed and applied.

Most of these joining and bonding techniques have been automated, and automation is now being extended to parts picking and setting, as well as distribution. Furthermore, the application of IoT is also expanding to visualize the entire production process, including the preventive maintenance of equipment, real time monitoring of welding, and total measurement of all dimensions for better vehicle body precision. Technical development aimed at bringing of AI and augmented reality (AR) to mass production lines will be the next step.

2. 3. Plastic Molding

Plastic molding processes are expected to not only realize appealing designs that make full use of the tremendous flexibility of plastic forming, reduce the weight of vehicle body parts, and enhance the textures of the vehicle interior, but also to reduce the energy generated in the manufacturing stage and to improve productivity. At the same time, plastic products have become larger to take advantage of this molding freedom and design opportunities, and are now required to both raise product value (value) and productivity (cost) to offset the large proportion of the vehicle and manufacturing costs they represent.

Reducing the weight of plastic parts has long been thought to largely depend on the cumulative experience of design and engineering experts. However, the use of CAE has greatly improved flow analysis and the accuracy of molding quality prediction and further optimized the plastic sheet thickness, making designs without waste possible. Furthermore, metal automobile parts are increasingly being replaced with parts made from plastic. In particular, CFRPs, with their potential to halve the mass of a part compared to steel, are now used not just for outer panels, such as hoods and roof panels, but also for vehicle frame parts.

Injection molding, which is characterized by the ability to produce complex shapes in large quantities with a high degree of precision, is used in the manufacturing process for plastic products. An array of methods to form molded items featuring higher quality, greater precision, extra functionality, and enhanced added value at a high production cycle have been developed for this technique. More specifically, switching from the conventional hydraulic injection molding to electric injection molding has made high repetition position control and high speed operation possible, greatly shortening the production cycle and improving productivity. Furthermore, CAE technology that predicts burr generation and deformation during mold release has been developed, shortening the production preparation period while also raising productivity.

Decorative technologies such as stitching and plating, often used on high-end luxury vehicles in the past, have been adapted to mass-market vehicles to realize more appealing automobile designs. Furthermore, in many vehicles, high-quality original molded parts made using special molding technology and colored plastic materials parts have been replacing parts decorated by painting or plating. Progress in automated driving vehicle technology has tended to increase the different types of processes required to attach the various sensors to exterior parts, making it necessary to generalize the secondary processing facilities and to ensure the process capabilities.

In terms of their contribution to the environment, plastic parts are currently the subject of development aimed at reducing the amount of CO_2 emissions and taking recycling into consideration. One specific recycling activity is material recycling involves pulverizing defective items generated during the manufacturing stage are for mixing into virgin material and used for production again.

With the growing adoption of IoT initiatives, one very actively examined technology is a means of acquiring and accumulating information, such as the actually measured pressure values during molding and forming, from manufacturing processes in real time. Advances in the optimization of plastic materials, processing technology, and mold technology have been achieved the realization of big data analysis, and products that will maximize business efficiency are likely to see the light of day soon.

2.4. Paint

Automobile manufacturers have been focusing their efforts on reducing the amount of CO_2 emitted from painting processes to reduce their impact on the environment. The painting booths, which produce the majority of CO_2 emissions in the painting process, have been refined and enhanced. Specifically, the intermediate and final coat booths, which were previously separate, were merged into a single booth performing an integrated process using three-wet painting. Also, the width of the booths was reduced thanks to the development of lightweight, multiaxial painting robots that can be mounted on the walls. In addition, high volume spray painting equipment capable of applying paint to a larger area at one time were developed, shortening the painting process by reducing the number of painting robots and allowing for compact painting booths. The broad availability of such environmentally-friendly painting technologies is leading to calls for these advances to be widely deployed throughout the automotive industry in the near future.

Recently, there are also growing expectations for advancements in production technologies that can respond to the rise in consumer demand to be able to buy their favorite color, even if they have to choose it as an extra option. With vivid colors, even a slight difference in the paint film thickness changes the color tone greatly, and ensuring that paint is applied uniformly constitutes a major challenge. Painting with higher added value is being achieved as highly precise digital technology off the painting line is used to gradually establish paint film thickness control technology.

Two- and three-tone multicolored outer panels have been increasingly chosen for styling in an effort to provide added value. Painting two or more colors onto a vehicle requires repeating the painting and baking processes as many times as there are colors, as well as a masking process to separate the different colors. This has led to issues such as longer production lead times and loss of productivity. Despite various attempted solutions, such as applying the second color in a separate, easily installed booth and oven outside the main painting line, and devising vehicle structures that simplify the masking work, the fundamental problems have yet to be solved. Some manufacturers have turned to techniques that apply different colors during a single painting process in the same way as monotone colors, but many equipment-related technical issues remain, and hopes are pinned on future technological developments.

Vehicle painting processes have been automated to reduce manufacturing costs and improve quality, and further labor saving and automation is being implemented to cope with the labor shortage in Japan. Automated technologies for applying paint and sealing materials to inner and outer panels, and for performing quality inspections after the painting process, are already established and widely used on painting lines. The next challenge will be to devise ways for robots and equipment to reproduce work processes that rely on human senses and extensive experience, such as polishing and correcting paint defects, making corrections after the application of sealing materials, and attaching clips, stickers, and other small parts. Initiatives to tackle this challenge through AI are underway. In addition, IoT is being used to collect and analyze various types of data and painting quality data, including the painting environment and conditions obtained via automation. The development of autonomous control technologies that predict paint film quality and automatically make corrections before defects occur is also underway.

2.5. Vehicle Assembly

In the vehicle assembly process, powertrain components such as the engine and chassis are mounted on the body the painting process is finished, and the various parts delivered by suppliers are then installed to complete the vehicle. After this, the final vehicle production process consists of a completed vehicle inspection to ensure quality. The type of part assembly differs depending on the destination and grade of the vehicle. A large variety of work procedures matched to the structure of the vehicle, including bolt tightening, fitting, and routing the wiring harness, are required, and manual labor by assembly line workers accounts for a large proportion of this work.

Japan's low birth rate and aging population have been intensifying the need to realize working environments that are friendlier to women and the elderly and do not impose a heavy physical burden. Example solutions to this issue include auxiliary equipment to help install heavy parts and the adoption of ergonomics analysis. Robots capable of coexisting and collaborating with workers are also being introduced into work processes to create working environments where tasks can be performed more efficiently.

In addition, vehicle assembly work performed outside Japan tends to be concentrated in emerging nations with very fluid labor forces, making it necessary to guarantee a stable level of quality. Consequently, it is desirable to create work processes that do not depend on the individual experience and ability of the workers. To prevent mistakes in judgment when selecting from different types of parts, manufacturers are introducing mechanisms that supply the workers with the complete set of proper parts for a single vehicle and other measures to avoid mistakes in the selection of parts. Manufacturers are also actively making use of unmanned automated guided vehicles (AGVs) to transport parts from suppliers within the assembly plant in an effort to achieve more efficient and lower cost vehicle production.

In terms of product trends, new vehicle structures and components have emerged with the rising adoption of electric motors on vehicles, various driver assistance technologies have been developed to satisfy growing consumer demand for better safety, and the testing of automated driving technologies on public roads has also begun. New inspection items have been added at production time to contend with updated communication technologies that go well beyond the concepts of conventional automobile production, as well as to respond to the creation of new quality assurance items. In an effort to provide better products to consumers at a lower cost, manufacturers are promoting space saving and greater work efficiency. In addition, global environmental concerns have made it desirable to realize assembly plants that are friendly to both workers and the environment.

The development of IoT technologies has also made it easier to visualize the current operating status of equipment and to perform real time monitoring of quality information. Such information is extremely useful for preventing abnormal stoppages of equipment or the recurrence of quality defects. Furthermore, predictions based on big data and AI are being incorporated to realize assembly plants that exceed consumer expectations by producing higher quality products with a short delivery time.

2. 6. Systems

In production technology, CAD, CAM, and CAE have become indispensable tools for solving problems such as shortening the development period of vehicles, improving quality, and reducing cost. At the same time, the influence of the Industry 4.0 trend in this field is also highlighting the issue of coordinating the various data items obtained from production plants at the time of production. The data collected from actual plants and equipment is selected according to purpose, with the results of analyzing this data fed into simulations and further analyses for use in the design of even better products and equipment. This information is, very gradually, being integrated into work duties.

Industrial 3D printers are also becoming more widespread. Leveraging the special characteristics of 3D printers is a promising approach in terms of optimizing vehicle structures, as well as of improving product functionality and reducing manufacturing costs by substituting current materials with other materials that have been difficult to apply up until now. The emergence of composite plastic materials has led to improvements in weight reduction technologies, paving the way for ongoing innovations in *monozukuri*. In addition, virtual reality (VR) is being used as a new technology for work habit training. Practical applications of new uses for digital data, such as assessing worker support or ergonomics based on combining elements of the digital world with the real world through augmented reality (AR) and mixed reality (MR) technologies, are also being examined.

The use of 3D scan data from within the plant has reached the level of practical application during the production preparation stage. For example, it is relatively easy to convert the pipes, pillars, beams, and shapes of equipment inside the plant into 3D data, which can then be used to check for any interference between equipment, investigate the possible introduction or removal of equipment, and examine the layout of the production line.

Big data analysis technologies are now often applied at manufacturing sites to collect and analyze a large amount of data from the production equipment and sensors, such as electric currents and vibrations. Product quality and equipment operating states that could not be identified until now are being analyzed from data collected in real time. Consequently, the use of this technology is rapidly expanding to improve product quality and perform preventive equipment maintenance. These technologies and data will be integrated into a virtual space called a digital twin, which will make it possible to use the current localized CAE simulation to construct another simulation of the entire plant and, within this digital space, examine how to best optimize it. In the past, software and systems have been adapted to the existing work processes, but these digital technology innovations will make it desirable to optimize processes to take maximum advantage of these new technologies.

3 Powertrain Production Technologies

3. 1. Casting

For the automotive industry, responding to increasingly stringent regulations on CO_2 emissions and fuel economy in the wake of growing concerns about protecting the environment and preventing global warming will require improving engine efficiency as well as reducing vehicle weight, air resistance, and the rolling resistance of tires even further.

The field of casting is also subject to growing demand for parts with more intricate shapes, thinner parts, and the integration of multiple parts, all in the name of reducing weight, which is the most effective way to improve fuel economy. Product complexity and demand for higher quality are also both continuing to rise.

In response to the need for higher quality, die-casting methods are increasingly replacing water-soluble agents with oil-based mold release agents, or spraying small amounts of undiluted mold release agent onto the metal molds instead of a large amount of water-soluble agent, to achieve high-vacuum die casting that allows heat treatments developed based on existing technology or to suppress the amount of gas generated within the metal mold. Similarly, low-pressure casting and gravity casting are increasingly adopting the mass production of inorganic cores molded from inorganic binders rather the conventional organic binders to suppress the generation of gas. Not only does suppressing gas generation within the metal molds lead to higher quality parts, it also contributes to improving the working environment at the casting plant and benefits the natural environment.

Calls to significantly improve development efficiency and shorten the production preparation period to respond quickly to rapid changes in market needs will continue to intensify, and high expectations are being placed on the analysis of big data obtained through the construction of a casting traceability system, expanded use of 3D data and X-ray CT scanners capable of non-destructive inspections, and the utilization of 3D printers, which are becoming more sophisticated year after year, as means of answering these calls. In particular, X-ray CT scanners are expected to be used off not only off the casting line, but also increasingly within the line to provide assurance about the total number of internal defects for highly difficult to cast products.

The aging population, falling birth rate, and decline in the number of laborers issues faced by Japan have led to efforts to improve the working environment and reduce the workload to address the aging of the workforce and the difficulty of securing enough workers. Along with cost reduction be achieved through rationalization, the use of IoT and AI technology in conjunction with the expanded automation provided by robots is attracting attention and expected to gain momentum.

3. 2. Forging

As efforts to protect the environment by reducing CO_2 emissions move forward, and automobiles worldwide are anticipated to address environmental issues through the more widespread use of electric motors.

Demand for more fuel efficient vehicles has risen sharply, triggering increased demand for smaller and lighter automobile parts. In the field of forging, various weight reduction efforts targeting parts are underway, including replacing underbody parts with parts made from lightweight materials, as well as the use of hollow steel parts since the development of hollowing technologies has reached the stage of practical application. Products such as precision forged gears also typify the ongoing efforts to further increase the precision of forged products. Dramatic progress being made in metal mold manufacturing technology, as well as the wider availability of stamping machines offering variable control of machining speed and forming motion, have had a large impact on achieving such products.

Lowering manufacturing costs will also be essential for production technology to raise the added value of forged products.

Improving the yield of hot forging parts has proven to be very effective at reducing the quantity of required material, saving energy, and reducing machining costs. Progress is also being made in the practical application of both closed die forging of differently shaped parts and deep hole molding of products with a long axis.

Reforming the working environment to make it friendlier to the laborers and to the natural environment has also become an important issue, and manufacturers are expected to institute further workload reducing measures such as improving the working environment by switching from dark-colored lubricants to lighter colored ones, inserting lighter refill work between processes that require heavy manual labor, and assigning more robots to processes involving loud noises.

A long-standing issue with forging methods is the need to make production lines more flexible and to shorten the development and production preparation periods to better cope with the production of multiple parts in various different volumes. In the field of forging, the precision of CAE simulation analyses has been improving year after year, greatly contributing to shorter lead times when developing new products, improved product yield, and the longer service life of metal molds and dies. In addition, IoT is being used to automate inspection work using image analysis, as well as to improve traceability, in an effort to contribute to reducing manufacturing costs.

The coordination of materials technologies, heat treatment technologies, and machining technologies is expected to lead to the development of new technologies that will enable forging products to better meet the needs of the market, maximize product functions and added value, and realize product manufacturing that achieves both good productivity and low cost.

3. 3. Machining

Stricter CO_2 regulations worldwide have led to greater diversity and increasing sophistication in modern powertrains. Examples include clean diesel systems, downsized turbocharged engines, CVTs, multi-stage ATs, and more electric-powered vehicles equipped with electric motors.

Automobile manufacturers around the world are especially expected to accelerate their plans to equip vehicles with electric motors in response to the strict emissions regulations in the EU.

Furthermore, flexible production systems are becoming a necessity to handle the growth of the ASEAN and Chinese markets and their bipolarization into a high-function product group and a low-price product group, as well as the growing complexity and diversity of consumer needs. Consequently, manufacturers are transitioning away from the conventional form of production dedicated to a single vehicle model to a cell production format based on a general-purpose facility (machining center) designed specifically for mixed flows of different models and capable of quickly and inexpensively handling multiple models produced in different volumes.

Other companies involved in automobile manufacturing are also adopting flexible transfer lines (FTL) in response to the production of multiple models in different volumes, and will be using a variety of approaches to make this transition to a cell production system, such as applying cell production only to lines with increased production or completely transitioning all of their lines to the cell production system.

The machining center plays an important role in the transition to cell production by helping to consolidate processes, and selecting tooling and jigs accordingly is necessary. In addition, as these highly-flexible production lines are deployed globally, their standardization is becoming critical to allow them to cope with multiple models being produced in different volumes and supplement production on a global scale.

Despite advances in high speeds and high feed rates aimed at greater efficiency, the speed of the spindles reaches several tens of thousands of revolutions and the high feed rate is approaching the thermal limit of the tool materials, which means that a technical breakthrough will be required in the field of machining. Advances in near net (final) shape machining will be required to reduce the need for traditional surface finishing, and collaboration between the materials departments and the machining field from the product design stage will become crucial.

Robots are increasingly used for conveyance and non-processing machines to respond flexibly to the production of multiple models in different volumes. Newer robots that can coexist and cooperate with people through the expanded use of AI will have to replace current ones to respond to changes in production even more flexibly. This technology is considered crucial not only to reducing labor costs, but also to address the employee recruitment problem, due to the significant decrease in the working population, especially in Japan. In addition, the demand to improve the working environment by automating visual inspections, simple work duties, and heavy manual labor is growing.

The field of machining is applying traceability systems to initiatives aimed at leveraging big data analysis of information collected from a variety of sensors to make equipment that does not stop due to malfunctions. Other initiatives are being carried out to improve product performance by reducing any variation in the machining precision and by shifting the target values. This involves analysis of the amount of position correction, vibration data, and measurement data from each piece of equipment.

3. 4. Heat Treatment

Heat treatments techniques are typically used to increase the strength of parts, and the main methods include carburizing and quenching, induction hardening and quenching, and soft nitriding.

In the automobile industry, heat treatments are widely used to improve the performance of basic functions of power transmission system parts, such as engine or transmission parts, and constant velocity joints.

Normally, carburizing and quenching is used for the treatment of gears such those in the transmission, while induction hardening is used for engine parts, constant velocity joints, and axle shafts. Soft nitriding, which does not induce any quenching transformation stress, is used for special applications when low distortion is required.

The increasing use of electric motors in automobiles has brought significant changes to the positioning of the power transmission system components. Downsizing these components has become an essential requirement due to the presence of batteries and the strength improvement required to handle the torque of the electric motor. Consequently, strength must be improved at both the material and heat treatment levels.

The carburizing and quenching process usually uses a large-scale gas carburizing furnace, but recently there have been many examples of manufacturers adopting vacuum carburizing to address environmental and safety concerns. Furthermore, manufacturers in the EU are switching from a liquid coolant to a more environmentally-friendly high pressure gas for quenching. In Japan, the very strict standards for handling high-pressure gas have delayed the adoption of this method. However, wider use is anticipated since it is possible to carry out quenching with a low-pressure gas of 1 MPa or less by performing the heat treatment with a small module.

Atmospheric heating and high-frequency (induction) heating were the prevalent methods for heating and quenching, but the lifting of certain patents and advances in infrastructure such as semiconductors are leading to the adoption of heating methods that use a laser or electron beam. In comparison to induction heating, these methods allow the application of heat with pinpoint accuracy, and are therefore used in the hardening and quenching of parts with complex shapes.

While the shot peening surface treatment method has typically been used to strengthen parts, surface coatings are being used to strengthen parts with special specifications in an increasing number of cases. This is a particularly effective method for lowering friction and improving wear resistance, but unfortunately it is also more expensive.

In simulations used to examine the effects of heat treatments, fluid analysis techniques have traditionally been used to model what is happening within the heating furnace and the cooling medium. These techniques have progressed and improved over time and can now perform heat treatment quality analyses that include variability.

It will be necessary to develop simulations that can handle new steel materials and cope with the increasing diversity of coolants used during quenching.

3.5. Powertrain Assembly

The diversification in the types of powertrains resulting from the rapid increase in the number of automobiles equipped with electric motors, coupled with the globalization of the production system and many other changes in society at large, has made the establishment of flexible production lines that can respond quickly to changing needs a pressing issue for manufacturers. At the same time, it is also important to improve competitiveness both on a global scale and in individual production plants. In Japan, the decrease in the labor force due to the declining population must also be addressed, and the need for automation to provide a solution is making itself felt more than ever before.

Although automation technologies utilizing industrial robots have become well established, the rapid advances in AI spurred by deep learning have made even more advanced automation possible. Automation processes previously built with special purpose machines can now use highly versatile robots as a base and be constructed with multifunction hands and an automatic hand exchange system. It has also become possible to automate tasks that used to be difficult to automate by coordinating the operations of multiple robots with the supply of kit parts. Such use of robots has made the production of multiple models on the same line easier, and robots that can coexist and cooperate with people enable the building of production lines that are more resistant to production fluctuations, more flexible, and more productive.

Product quality is also improving thanks to automation technologies. Higher performance and higher speed camera systems and image analysis functions, along with higher performance sensors provide more advanced inspections than in the past, and combining these systems with robots has made it possible to carry out numerous inspections at high speed and without variation. The next step in this field will to expand the scope of practical applications of robots through greater coordination with AI in pursuit of unlimited unmanned production processes.

As the digitization of the manufacturing industry advances and IoT evolves and spreads at a breakneck pace, these advances are capitalized upon to ensure improvements in productivity, quality, and traceability. In the future, even larger amounts of data will be collected and analyzed from the production lines, the products themselves, and even the state of product usage in the market. The construction of a system that can reflect these analysis results on the production line in real time has already accelerated, and realizing the cost and quality demanded by the market is expected to become possible.

Japanese manufacturers will need to make wide use of these technologies and improve the competitiveness of their production lines even further if they are to meet the expectation of overcoming their international competitors.