PRODUCTION TECHNOLOGY AND PRODUCTION SYSTEMS

1 Introduction

The entire automobile market in 2015 was approximately 90 million vehicles, a result exceeding that of 2014. However, the situation remains unpredictable given the slowdown of growth rates in regions other than North America and Western Europe, and the continuing decline in the number of vehicles sold.

On the other hand, consumer interest in vehicles with low CO_2 emissions and excellent fuel efficiency, such as hybrid vehicles (HV), continues to grow, and automobile manufacturers are promoting the further development of their technologies. These include vehicles that stop safely when they detect a driver error or other mistaken operation, as well as the development and application of self-driving vehicles.

In 2015 there was also growing interest in the concepts of Industry 4.0 and the internet of things (IoT), so many companies began implementing new activities to collect and utilize the information coming from their production plants.

In the field of production engineering and technology, automakers are presented with an extremely stringent demands to produce vehicles that are lightweight, exhibit high levels of precision and performance, as well as to make full use of all the facilities they own to achieve safe and highly-efficient production.

2 Vehicle Production Engineering (PE) Technologies

2. 1. Stamping

The environment surrounding automobile manufacturers and the initiatives they are taking to improve vehicle safety are becoming increasingly competitive with each passing year, a situation that is leading to the development of lightweight and high-strength vehicle bodies that are both light and possess excellent collision safety performance. Consequently, the application of high-strength materials (ultra-high tensile strength steel sheets, hot stamping, etc.) to the vehicle body frame members has only continued to increase. Some manufacturers are substituting aluminum materials in place of steel to reduce vehicle weight, and some luxury cars are even being built with carbon fiber reinforced plastic (CFRP).

The high tensile strength and springback of ultra-high tensile strength steel sheets lead to problems with the accuracy of part dimensions, impeding their wider adoption. This problem has been addressed through the use of material models that take the Bauschinger effect into consideration, thereby improving the predictive accuracy of simulations, which makes it possible to improve the forecast accuracy of the stamping dies and to design shapes that reduce springback. In addition, advances in the development of materials with improved formability have enabled the use of steel materials in the 1,180 MPa class for some parts where 980 MPa class steel was considered the limit in the past. Materials that exceed the 1,180 MPa class are also being developed, requiring new efforts to respond to these even higher strength materials.

The hot stamping process involves heating the material to a high temperature and then rapidly cooling and quenching it within the die after press forming to force a martensitic transformation that allows it to attain a very high strength (1,500 MPa or higher). In comparison to press forming at cooler temperatures, this hot stamping method is characterized by better formability and fewer problems with dimensional accuracy. However, the time required for the heating, cooling, and laser cutting of the material slows down production speed, which currently limits this method to use only on certain vehicles due to production efficiency concerns such as short die maintenance periods. New methods, die structures, and production equipment are being developed to address these issues and allow the use of hot stamping for a broader range of vehicle models. In addition, other uses for the hot stamping method, such as tailored blank material, forming spot welding materials, and even controlling the cooling range and speed to soften the strength of certain portions of parts, are being developed and are expected to further expand the scope of its usage.

The application of aluminum materials to the vehicle body is expanding mainly to covers, such as hoods and front fenders. The Young's modulus of aluminum materials is one-third that of steel or iron, resulting in a large amount of springback. In addition, its low elongation rate at room temperature makes it is a difficult material to work with as it is prone to cracking during drawing and bending. Aluminum materials also generate a lot of chips and shavings during the cutting process and have a soft surface, making contamination by dust from these shavings or other sources a frequent cause of defects in the external appearance. Consequently, aluminum has been used in limited cases on sports cars and luxury vehicles. However, as simulation technologies advance and measures applied to the structure of stamping dies gradually resolve these problems, the number of parts that use aluminum is expanding.

Since adopting new materials and construction methods tends to increase the cost of the automobile body, efforts to reduce this cost are important. Consequently, the design, procurement, and production divisions of manufacturers are coming together as one from the earliest stages of the vehicle design to ensure that things such as the number of die stamping processes, the division of parts to optimize the material yield, the shapes of the parts, and the forming plan are all being incorporated at the same time.

Consumers are not only concerned with the basic functions and price of a vehicle. They also place a strong emphasis on the vehicle's design. Thus, they often seek out vehicles with sharp body lines and beautiful designs that really stand out, new stamping and forming technologies are being developed in response.

2. 2. Welding

In recent years the performance demands for automobile bodies have only been increasing. A high level of collision safety performance is required to meet the stricter collision testing modes, the bodies need to be lighter so that they can contribute to improving fuel efficiency, and they must also have high rigidity to provide a more comfortable ride. The use of high-strength materials (e.g., ultra-high tensile strength steel sheets, hot stamping) for the main frame components of the vehicle body has expanded, and in some luxury vehicles steel materials are even being replaced with CFRP or aluminum alloys (e.g., extruded materials, casting). New joining technologies are also being developed and applied to realize higher rigidities between joined parts.

When spot welding is used on high-strength materials, the higher electrical resistance than in mild steel sheets causes the heat balance to deteriorate when the two are combined, which makes it more difficult to form the nugget on the mild steel sheet. The number of such difficult to weld locations has been rising. Ensuring the quality of welds has also become more difficult. For example, peeling strength decreases due to a decline in the ductility of the welded portion and the heat-affected areas, while delayed fracturing may occur due to the state of strain of the welded portion and hydrogen contamination at the time of welding.

To weld aluminum alloys, any of the following methods may be used depending on factors such as the structure of the weld location and the required strength: self-piercing rivets (SPR) used in combination with an adhesive, flow drill screwing (FDS), TOX, blind rivets, or friction stir welding (FSW). These welding methods have been developed with a view toward the mixed production of steel bodies and multi-material bodies.

With CFRPs, the large difference in electric potential between the carbon fibers contained within the material and steel sheets or aluminum alloys make additional processing, such as cationic electrodeposition, necessary. Conventional rivets and bolts can be used to bond CFRP to other materials and itself, and some manufacturers are also beginning to use only adhesives for bonding. Other bonding methods using lasers, electromagnetic waves, and FSW are also under development.

Shortening the pitch between welds is one method to increase the rigidity of the bonded joint between parts that has been put into practical use. This can be achieved through the use lasers to place additional welds between the conventional spot welds, or by carrying out a distribution analysis through simulation and then shortening the pitch between the spot welds accordingly. Another method used more and more frequently to increase the rigidity of the vehicle body is to expand the range over which the adhesive (Weldbond) is applied to the joint between the components.

Up until now, the quality of spot welds was commonly checked by driving a chisel into the spot welded nugget to check the state of the joint. However, using a chisel on a high-tensile strength material may cause cracks to form in the nugget and decrease the strength of the weld. This is why non-destructive weld inspection methods, such as using ultrasonic waves or magnets, are now increasingly being used. In addition, manufacturers have also started moving toward monitoring the resistance waveforms of the entire automobile body during spot welding and then collecting and storing this data through their network. This massive amount of data is then used to analyze the relationship between the resistance waveforms and the welding quality in an effort to control the quality of the welding work.

2. 3. Plastic molding

In recent years plastic molding technology has been asked to meet the ever-increasing demand for better environmental protection, as well as to contribute to providing customers with even more value. In concrete terms, this means taking full advantage of the lightness of plastics, which is one of the material's strengths, to contribute to the production of lighter vehicles with better fuel efficiency and improved handling. The tremendous freedom to mold plastic into almost any shape is also being utilized to realize inspiring designs and to meet the demand for enhanced textures that provide even more comfortable vehicle interiors. In addition, it must be possible to manufacture these plastic molded parts in a highly efficient manner and then deploy them reliably on a global scale in a timely fashion.

On the exteriors of vehicles, plastic materials have long been used for bumpers to help reduce weight, but it has now become common for the entire front end of the vehicle to use a design comprised of plastic materials. The increasing use of plastics is spreading to other parts of the outer panels and they are now commonly used for fenders and back doors, while retaining their main role of improving on the performance of conventional materials. The back doors of modern vehicles are composed of many parts, and using plastic for those parts not only reduces vehicle weight, but also allows for the integration of peripheral components, which in turn helps to reduce cost.

There have also been cases where CFRP was used for the roof and even the frames of electric vehicles and low-volume production sports cars to achieve unparalleled levels of weight reduction. There are still many issues to overcome, including the unit price of the raw materials and the length of the processing time, as well as the challenge of deploying CFRP parts on a global scale. However, the development of new manufacturing methods and the development of materials that use thermoplastic resin with higher levels of productivity are being tackled from many different quarters. Consequently, it is expected that CFRP will be far more widely used in the future as the mass production of this material becomes a reality. The use of plastic materials is no longer limited to just the interior and exterior. Their use within the engine compartment is also steadily increasing and almost all the air intake parts on the low-temperature side of the engine, with the intake manifold being one good example, have now been converted to plastic. At the present time, the rapid improvements being made in the performance of plastic materials are demonstrating that their use in the high-temperature regions of the engine, such as the engine cooling system parts, oil pan, and piston head covers, is only going to continue to expand.

To enhance the textures of plastic parts, certain methods borrowed from higher-priced vehicle models, such as the addition of conventional decorative parts and highly decorative paint, are now actively being employed and their use expanded to mass-production models in an aim to improve the product appeal of these vehicles. Initiatives such as these are also being promoted to achieve levels of texture quality that are equivalent to or higher than those on luxury vehicles with a higher degree of efficiency. For example, a plastic part for the instrument panel conventionally manufactured using slush molding was replaced with a part made by injection molding of TPO material. In addition, plastic part manufacturing methods that achieve both a high sense of tactile feedback and a reasonable cost are being developed along with new plastic materials that utilize a high degree of transparency to express beautiful colors while also possessing improved weather and scratch resistance. Such initiatives seek to improve the textures of plastic parts while also playing a role in efforts to simplify production processes by, for example, abolishing the need for painting plastic parts, and contribute to the reduction of CO_2 and VOC emissions. There are already techniques for putting the appearance of stitches into leather and synthetic leather to give the vehicle interior a stronger feeling of refinement and luxury. However, in an effort to improve the efficiency of production and reproduce the look of a high-quality grain and the shape of seams in a plastic mold, new technologies that allow for stitches to be sewn into an injection-molded three-dimensional form are being developed and introduced.

In an age when IT is evolving and information is being transmitted around the world instantly, information about a new vehicle must be delivered to customers around the world at the same time as this new vehicle is introduced to the market. Consequently, it is also critical to ensure that all mass production preparations have been completed. The most important thing is to make sure that all the conditions for a high-quality, non-defective product have been thoroughly incorporated into the product and process design before beginning to create the dies and molds. This means that CAE must be employed to predict issues such as changes in part dimensions and molding warpage caused by the temperature changes unique to plastic, and that design-stage quality verification technologies to address those issues are also becoming increasingly more crucial.

Automobile manufacturers are being asked to anticipate the changes coming to materials technologies, processing techniques, die technologies, analysis technologies, and product design techniques, as well as to raise their own capabilities in all these areas to provide a high amount of value to their customers in a timely manner.

2. 4. Painting

Many paints used In automobile painting processes contains volatile organic compounds (VOCs) and the air conditioning for the painting booths as well as the baking processes consume a lot of energy and emit a lot of CO_2. Consequently, reducing the use and emission of substances hazardous to the environment is a major issue for the entire automobile industry, and over the past several years, all manufactures have been implementing various initiatives to contribute to the prevention of air pollution and combat global warming.

The automobile industry has been making steady progress in reducing the amount of VOC emissions from its automobile painting processes. Conventional base paints for the intermediate and final coats have been replaced with waterborne paints, and clear paints have been replaced with high solid paints. Painting processes have been improved through the development of high-efficiency painting technologies and the adoption of uniform film thicknesses to reduce the overall amount of paint used. Various painting facility measures have also been put into place, including the introduction of devices to treat the emissions from the painting processes and the collection of waste paint thinner.

On the other hand, when it comes to efforts to reduce the amount of CO_2 emissions, the amount of energy used in the painting processes has actually increased as a result of the efforts to reduce VOC emissions, such as the use of waterborne paints and emissions treatment devices, and so it has become difficult to promote CO_2 reduction. However, in recent years, some progress has been made in reducing emissions due to efforts to shorten the painting processes by consolidating process functions, reducing the amount of space that processes and equipment require by making them more compact, and reducing the amount of energy that the heating processes use. The following are some concrete examples of how the number of painting processes has been reduced. Intermediate coat drying furnaces have been eliminated due to integration of the intermediate and final coating processes and the introduction of the three-wet painting process. Sealer drying furnaces have also been eliminated by making improvements to the paints and processes being used. The entire painting process has been shortened by optimizing the means of heating in the preheating process.

In recent years manufacturers have also stepped up efforts to provide their customers with an even higher value product. Amongst consumers, the demand for higher quality paints with improved durability and a more appealing finished appearance, and interest in highly decorative paints, is growing. However, as the number of layers of paint and the film thickness increase, the amount of VOCs, CO_2 emissions, and cost all rise as well. A comprehensive solution that balances environmental protection, product quality, and the economic feasibility of the product is now more important than ever.

The contributions made by paints are also continuing to expand in the areas of vehicle quietness and ride comfort. Sealers and undercoats are increasingly being used for soundproofing purposes, damping materials are being optimized, and foam materials are also used with increasing frequency for functions such as sound insulation, sound absorption, and rigidity.

As mentioned previously, there is strong demand for better vehicle fuel efficiency through reduced vehicle weight. Consequently, aluminum materials are being used for a wider range of parts and lighter plastics often replace heavier materials. This leads to a growing need for improved color matching technologies that can handle all of these different materials. In addition, the materials that constitute the paints themselves are also expected to contribute directly to vehicle weight reduction by reducing the specific gravity of low viscosity paints such as sealers and undercoats, and reducing the total amount of paint applied to the vehicle through higher efficiency painting technologies.

2. 5. Vehicle assembly

The vehicle assembly process is the final automobile manufacturing process that leads to a completed vehicle. After the body is assembled, proceeds through the painting process, and receives its surface treatment, powertrain components, such as the engine and chassis are mounted on the body, and then the many parts produced by the suppliers are installed. Parts are selected in accordance with the shipping specifications and multi-model mixed production is often carried out on a single production line. A large variety of different work procedures must be performed in accordance with the vehicle's structure, such as tightening, fitting, and routing the wiring, making vehicle assembly a very labor-intensive process comprising many steps involving hands-on, manual work.

In Japan, young people are moving away from the manufacturing industry and older workers are staying employed for longer periods. This means assembly processes must be designed to be efficient and make tasks easy to perform. In addition, the vehicle assembly work carried out overseas tends to be concentrated in developing nations with very fluid labor forces, so various schemes have to be devised to help ensure that a stable level of quality is ensured. As a result, assembly lines are being designed to place less of a physical burden on the assembly workers and auxiliary equipment to help lift heavy objects has been introduced. Part supply schemes that provide a single vehicle's complement of parts as a single set so that workers can retrieve the necessary parts without having to make decisions have also been introduced, as have a large variety of fool-proofing devices. All automobile manufacturers are designing their assembly processes to be as worker-friendly as possible and make assembly mistakes unlikely. In the near future changes to labor laws and regulations are expected to also make it possible for collaborative assembly robots to coexist with, support, and work alongside other assembly line workers.

With manufactured products, it is necessary to bring high-value, low-cost products to the market at an early cycle. Consequently, all automobile manufacturers are seeking to collectively design multiple vehicle models with the same platform and are implementing vehicle development strategies that attempts to use common parts and vehicle structures. These strategies will also make it possible to have common installation standards and tightening conditions that contribute to reducing investments in facilities and equipment as well as the number of work hours. On the other hand, as many materials used in vehicle construction are being replaced with ultra-high tensile strength steel sheet, aluminum, and even plastic for the purpose of improving the fuel efficiency and collision safety, and as electric vehicles and fuel cell vehicles move closer to true mass production, the conventional vehicle structures, assembly processes, equipment, and quality assurance methods will have to be modified. In addition, advanced safety systems that use radar and cameras are increasing in number every year and the development of new technologies that lead to automated driving is also advancing. More and more new vehicle structures and adjustment testing processes, which will become the core elements of the development of new technologies in the vehicle assembly field, are being created in response to these advances.

Innovative digital tools are being introduced into the field of mass production preparations in an effort to complete the productivity verification work at an early stage and shorten the preparation period. It has now become possible to evaluate data using virtual reality via a goggle-type display. In comparison to the conventional stationary-type display screen, this makes it possible to evaluate the assembly work with the same visibility and work posture that an actual assembly line worker would have. In addition, the use of 3D printers to evaluate actual prototypes, such as parts and jigs, has sped up the production process and helped contribute to lower costs and faster verification cycles.

To carry out mass production quality control for the processes that have transitioned to production, the utilization of big data is being promoted with regard to the operating conditions and quality control that are carried out with a variety of measurement instruments and condition monitoring. In addition, the utilization of big data to maintain high product quality with good efficiency based on Industry 4.0 is also being promoted. The collected data is also expected to be used to improve the next-generation product design and process designs.

3 Powertrain Production Technologies

3. 1. Casting

To address the demand for reduced automobile CO_2 emissions to combat global warming and reduce the amount substances hazardous to the environment, efforts to make gasoline engines highly efficient, develop hybrid vehicles, and develop electric vehicles, must also be complemented by a decrease in the overall weight of vehicles. The necessity of introducing very fuel efficient and low-priced vehicles to the market in a timely manner means the production divisions at automobile manufacturers are being tasked with finding ways to shorten the lead time from vehicle development to mass production while also raising the quality of the vehicle to a high level and reducing the cost.

As a part of efforts to shorten this lead time, the use of integrated 3D data from the time of simultaneous development and production design, to the productivity assessment, and finally to the creation of the molds and dies has expanded greatly in recent years. Casting simulations have also been used from the initial stages of development in order to improve the degree of completion. This allows the behavior of the molten metal in the die during the filling and solidification processes to be predicted, and then fed back into the product shape as well as reflected in the die design in advance so that the product quality can be built in before the actual casting is carried out. In recent years these casting simulations have not only been used to predict the behavior of the molten metal in the die during the filling and solidification processes, but also to predict things such as the potential deformation of product dimensions. In the future, the diversification of the analysis methods and expanded scope of these simulations is expected to result in shorter lead times, improved quality, and reduced cost.

A large array of aluminum materials are now used in automobiles, but one of the most widely used manufacturing processes is aluminum die casting. There are many examples of this process being used to form parts for the vehicle powertrain, such as engine parts and transmission parts, and many of these parts play critical roles that impact the performance of the vehicle. The optimization of the construction methods and casting designs that had been used up until now allowed the manufacturers to take existing parts and make them thinner, lighter in weight, and higher in quality. In recent years, the application of vacuum die casting has made it possible to carry out solution treatments and welding that used to be more difficult and this in turn has meant that the application of aluminum parts has been expanded to structural components of the vehicle body that require high functionality. Consequently, for the field of metal part casting to provide the new functional parts for next-generation of vehicles in a timely manner, it is critical that the product development, production engineering, and production divisions work together as one in the future and force manufacturing to evolve.

In the field of metal part casting, a traceability system that ties the casting conditions and quality inspection results to the product is being used to assure the quality of the parts that are produced and improve that quality over time. The manufacturing ID that ties the product to its manufacturing history is converted into a 2D barcode which is then laser engraved on the surface of the product so that different products can be identified. This system makes it possible to measure and control the casting conditions within the production process that may affect the quality of the products. Then, the manufacturing conditions are collected and analyzed so that this information can be used to ensure the quality and clarify the mechanism causing any variations in quality within the manufacturing process. Furthermore, the collected data is also used to improve the analysis conditions and evaluation criteria of the casting simulations and this is expected to contribute to an improvement in the verification accuracy.

3. 2. Forging

Forged parts comprise the power transmission components of highly efficient internal combustion engines, hybrid vehicles, and electric vehicles. Consequently, there is growing demand for precision forging that can help to reduce and shorten the cutting process and also for the development of new forging technologies that may lead to lighter forged parts in an effort to reduce the amount of CO_2 emissions, save energy, and lower cost.

A good representative example of precision forging is the forging of small gears. Some manufacturers have begun promoting the practical application of extrusion forging to form gears with crowning added to the tooth surface of the gear with a precision down to 5μm. Even in the case of module 2.0 or greater gears, research is continuing to be carried out into whether or not forging that utilizes a divided flow to facilitate the flow of material into the forming site can be used to reduce the forming pressure and thereby improve the filling.

The use of a servo press for cold forging is growing in popularity and manufacturers are continuing to improve the precision by controlling the press motion. Control that uses a pulse motion to reduce the friction between the material and surface of the die improves formability, extends the service life of the metal dies, and reduces the required processing power, which in turn results in other positive effects, such as improved productivity and reduced energy usage. Another approach involves optimizing the processing speed to change the elastic and thermal deformation of the tools and materials in an aim to realize even higher levels of precision. It will become necessary to develop control technologies that allow for the selection of the optimal motion that corresponds to the specific purpose, such as reducing the processing load or increasing precision, and these control technologies are expected to continue enjoying widespread adoption and use.

Giving a hollow structure to parts that have a long axis is being promoted as a technology to help reduce weight. Forging in deep hole machining where the length divided by the inner diameter of the part is 10 or more has now become possible, and this has garnered attention as a technology to help reduce the weight of transmissions. The use of high-strength steel sheet is expanding in hot forging as well, and the use of untempered steel that contains trace amounts of vanadium alloy is also starting to be more widely used. After forging, the cooling speed of this material is controlled to trigger precipitation hardening of the vanadium, making it possible to omit the quenching treatment after forging. Consequently, this not only saves energy, but also gives the material a higher strength due to the increase in vanadium, thereby reducing weight. Recently, however, some manufacturers have begun using untempered steel that does not contain any of the rare metal vanadium for the purpose of reducing cost.

3. 3. Heat treatment

The heat treatment process is absolutely essential to improving the strength of parts that transmit the driving force within the vehicle, such as the engine, transmission, and axle. In an effort to reduce the size and weight of these power units, as well as to improve their durability, various technologies to increase the strength of the steel material in these critical parts have become widely used. Furthermore, the efficient consumption of energy in the mass production processes that produce these parts is becoming an important issue.

Carburizing and quenching is the representative strengthening process for gears and other metal parts. In this process, the gas carburizing heat treatment requires temperatures close to 1000℃ and large amounts of combustible gas are consumed to maintain the non-oxidizing carburizing atmosphere. Consequently, manufacturers are increasingly moving away from this gas carburizing system to a vacuum carburizing system that allows for the amount of carburizing gas that is consumed to be reduced to less than a few percent because the system is under a vacuum. The non-oxidizing performance of vacuum carburizing is remarkably excellent, and the fatigue strength of the steel is improved since harmful oxide layers are not generated at the grain boundary of the product's surface.

Furthermore, this dramatic reduction in the amount of gas used for the carburizing process is also advantageous because it reduces the risk of fire hazards. Therefore, vacuum carburizing systems are now the main choice when replacing aging equipment in Japan and when making new investments in overseas production bases. The continuous gas carburizing systems used up until now allowed manufacturers to maintain their cost competitiveness through mass production with a single set of heat treatment conditions, which meant that it was inefficient to switch to a different set of conditions. However, with a vacuum carburizing system, a small-size batch furnace is used and the conditions can be set at will to match the needs of each different lot module, making it possible to select the optimal conditions for each product. There are a large variety of mass production technologies being developed, such as adjustment of the carburized depth and the grain size, fine dispersion of carbon nitride, and a two-phased metallic structure.

Gas soft nitriding is the representative heat treatment process that results in low strain and no impact from quenching transformation stress. The adoption of nitriding potential control is being promoted as part of a system for more efficient consumption of the NH3 nitriding gas. Nitriding potential control reduces the amount of wasteful NH3 consumption by using a hydrogen sensor to monitor the amounts of N2 and H2 that the NH3 is decomposing into within the furnace and then controlling it. In addition, research into the optimal value for improving the vulnerabilities and inhibiting the growth of the compound layer on the surface of the product was also established. The database of these control target values in the form of Lehrer diagrams has been made widely available and as a result new mass production technologies, such as deep depth nitriding and high-density nitriding, are being developed based on improvements to the compound layer.

3. 4. Machining

Recent years have seen a growing diversity and a growing level of sophistication in engine types and powertrain units. Examples include hybrid vehicle engines, clean diesel engines, and turbos with small exhaust volumes, as well as dual-clutch transmissions (DCT), automatic shift MT, CVT, and Step AT. Consequently, there are increasing demands for highly efficient production that is also flexible enough to be able to handle multiple vehicle models.

In the field of machining, to handle the move to shorter vehicle development periods, most production plants in Japan and overseas are reducing their production of single vehicle models using dedicated equipment. Instead, they are expanding their use of flexible production lines that employ general-purpose equipment to produce multiple vehicle models in various volumes.

In the machining processes that work on boxy aluminum parts, such as engine blocks, heads, and transmission cases, there are now examples of manufacturers switching from a series of processes with transfer machines to machining centers with parallel processes in an effort to integrate the machining processes. The issue with parallel processes is how to make them highly efficient. Promoting the standardization of jigs and cutting tools is helping to improve the ease with which production lines can switch to other vehicle models. In the machining processes that work on cylindrical steel parts, such as engine crankshafts and camshafts, the abundance of different construction methods becomes a bottleneck and it is difficult to configure a production line that consists mostly of general-purpose equipment. Consequently, there has been a growing tendency to expand the use of combined processing machines that can integrate multiple processes, such as turning, drilling, and milling, together.

In the past, traceability systems were used to ensure the quality of parts from the machining lines that worked on powertrain components. These days the effective utilization of big data based on the concepts of Industry 4.0 and the IoT is also expanding as a compliment to those traceability systems. The amounts of position correction, which are different for each piece of machining equipment, and the machining characteristics measurement data are collected in large amounts. The results of analyzing this data are then fed back into the machining equipment and the product (vehicle). This in turn leads to plans to improve the vehicle functions, such as fuel efficiency, and also reduces the variation in quality accuracy.

3. 5. Powertrain assembly

There is growing demand for the construction of multi-product, variable volume production systems that can meet the diverse needs that are changing every year for gasoline engines vehicles, diesel engine vehicles, HEVs, EVs, and FCVs. These production systems must construct lines that can continue to operate with high productivity and also build high quality vehicles. At the same time, they should be responsive to the changing needs of the market and help address the common issue of shorter mass production preparation periods. There are major expectations for such production engineering technologies.

The modularization of vehicle structures is being promoted to ensure high levels of productivity in multi-product, variable volume production. The parts and structures unique to one vehicle model are assembled during the sub-assembly process to the full extent possible, so that even if the vehicle model on the main line changes, the same assembly work can be carried out as much as possible. In contrast, some manufacturers are examining automatic assembly lines, but expanding the applicable range of assembly robots will require introducing coexistence-type robots that have fully taken safety into consideration to enable people and robots to work together cooperatively. Other manufacturers are employing automated guided vehicles (AGV) to perform some assembly processes without the use of a conveyor. Vehicle production and assembly is always advancing in an effort to achieve even higher levels of flexibility.

In the area of product quality, information such as the assembly date and time, process, assembly result, and inspection data, is being tied to each individual production unit within the production line based on the concepts of Industry 4.0 and the IoT. This big data from mass production is then stored and is starting to be used for many different purposes, such as managing quality trends, quickly discovering defects when they occur, identifying the causes of defects and developing countermeasures, and improving the efficiency of production.

The data collected from the assembly processes can also be used for a variety of other purposes. Of course, it can be used to reduce the amount of variation in mass production, but it can also be used to identify the factors that are affecting the performance of the vehicle (for example, fuel efficiency and NV characteristics), and possibly even lead to the improved marketability of the unit by providing feedback to the development division.

Given the truly massive amounts of data that are being obtained each day, the major issue here is being able to identify the data that is really relevant to a specific purpose and then finding a way to use it effectively.

Bringing together the development divisions, production engineering, production plants, and members of the supply chain is expected to become crucial to strengthening the production system so that it can achieve both product functionality and productivity at a high level all the way from the initial concept and design stages of the vehicle.

4 CAD, CAM, & CAE

CAD and CAM systems are absolutely essential tools for production engineering and production technologies because they allow the product to be built as intended by the designers and engineers.

In recent years, the rapid progress (e.g., miniaturization, high speed, low cost) being made in hardware (computing devices and memory) and advances in software have made it possible to reproduce various phenomena and conditions of the manufacturing site within the computer. The solid modeling of products and production equipment has advanced and it has now become possible to define and utilize products and dies while they are still in their mid-processing shapes. Advancements in various sensors and measuring instruments have greatly sped up the measuring of product and production equipment shapes so that this information can now be supplied as feedback, which in turn improves the precision of analysis. The precision of this analysis is also much better than it was in the past (the number of elements is large) and it is now possible to complete the analysis in a practical processing time.

Using these technologies has made it possible to evaluate the production conditions before any products roll off of the assembly line.

These evaluations are not just limited to verifying the amount of time needed for fabrication or the machining precision of the production equipment either. The shape of the product after welding and assembly, as well as the precision and quality of painted surfaces, can now also be verified in advance.

As a result of all these technological advances, digital prototyping, and even the concept of prototype-less production are starting to become a reality.

References
(1) Website of JSAE