Production Technology and Production Systems

1 Introduction

The vehicle market in 2013 was strong as the U.S. market continued to be robust and the European market finally showed signs of recovery. In contrast, growth in previously rapidly expanding emerging markets slowed. The Japanese market also showed signs of a recovery, such as improved consumer confidence, as a result of the so-called Abenomics policies of the government. However, this situation does not allow for much optimism in the long term, even considering the expected surge in demand prior to the increase in the consumption tax. Despite this economic situation, the 43rd Tokyo Motor Show attracted 900,000 visitors, 60,000 more than the previous event. This shows that the level of interest in new vehicles is still high. In the exhibits at the show, automakers emphasized environmental friendliness and safety, as well as the appeal of design and high performance. In addition to continuing to address environmental concerns through sophisticated products like hybrid vehicles and high efficiency engines, the show also introduced other products that adopted new materials, such as ultra-high-tensile strength steel to reduce weight, as well as aluminum, plastic, and carbon fiber reinforced plastics (CFRPs) as alternative materials. High levels of basic technologies will be required in the future as new vehicle designs adopt shapes that are difficult form, and production engineers will be required to pursue even greater levels of quality, cost, and delivery (QCD) for mass-production.

2 Vehicle PE Technologies

2. 1. Stamping

The competition between automakers to make vehicles safer and more environmentally friendly is intensifying every year. High-tensile strength steel sheets for frame components, hot stamping methods, and aluminum materials have all been adopted to increase passive safety while reducing the weight of the vehicle. In fact, these technologies are already becoming commonplace. High-tensile strength steel sheets are also being increasingly adopted in exterior panels to reduce weight even further. Each year, the external appearance of vehicles seems to require ever more complicated designs that are difficult to create by stamping to increase the appeal of the vehicle to the consumer. As a result, there is an urgent need to improve stamping forming technology.

First, as the use of high-tensile strength steel sheets in vehicles have increased, challenges include formability, dimensional accuracy, die strength, and productivity. In particular, poor dimensional accuracy due to spring back is a big problem.

High-tensile strength 1,180 MPa class steel sheets, which are stronger than 980 MPa class steel sheets, have been adopted in the frame components of mass-production vehicles and efforts are also being made to use such high-tensile strength steel in exterior panels to improve safety and reduce weight. Consequently, other efforts are being made to address spring back of this steel within the die through compensation technologies, technologies to minimize spring back, and more precise simulations.

Hot stamping allows steel to obtain a strength of around 1,500 MPa after forming by keeping the steel extremely hot and soft during forming and then quenching it via the surface of the die. This strength changes depending on the temperature history of the material due to the cooling provided by the surface of the die. Therefore, controlling the temperature history during production is very important. Unfortunately, this process requires some time to heat the material and then quench it after forming, so productivity is lower than cold stamping. In the future, the methods used to heat the materials and quench the dies will be improved to promote greater use of hot stamping. This in turn will shorten the cycle time and the manufacturing process will be improved to address the challenges of increasing the number of units produced per hour while also reducing the energy cost.

Aluminum is increasingly being used in place of steel sheets for closure parts, especially hoods. Due to a low Young's modulus, which is only one-third that of steel sheets, aluminum also has a large amount of spring back. There are also issues with chips, which are generated easily during trimming processes and adversely affect productivity. As a result, it is critical to improve die compensation, optimize processing conditions, and enhance technologies such as die surface treatments.

The cost of stamping parts has been reduced by efforts to improve yield by optimizing part shapes and reducing excess thickness, as well as by promoting the use of leftover material that would normally be considered scrap. These kinds of positive improvements are being promoted through close cooperation between design, purchasing, and PE departments starting from the vehicle development stage.

In recent years the importance of the vehicle's design has increased more and more in the eyes of consumers, in addition to safety, fuel efficiency, dynamic performance, and price. As a result, modern vehicles are required to have sharp exterior lines and bold design cues. Even more advanced stamping technologies will be required to realize such designs.

2. 2. Welding

One key trend in 2013 was the selection and replacement of body materials to help reduce weight. In addition, measures were also taken to innovate body structures and provide greater body stiffness through improvements in joint bonding strengths. These efforts are clear signs of attempts by all automakers to achieve both lower weight and excellent body stiffness.

High-tensile strength steel sheets are being increasingly applied to main frame components along with the use of more materials with even higher strengths. Hot stamping parts are now being used on mini-vehicles, in addition to mid-size and large-size luxury vehicles, and the adoption of these parts is likely to continue accelerating in the future.

Materials other than high-tensile strength steel sheets became thinner and the number of weld spots tended to increase to compensate for decreasing joint strength.

One difficulty is that, as the strength of high-tensile strength steel increases, it is more difficult to perform spot welding on these materials. The number of difficult locations for spot welding will continue to increase due to the combination of different types of steel and the number of sheets that are used. In recent years, automakers have begun utilizing spot welding simulations to select the welding conditions, and these simulations will likely become more prevalent in the future. In addition, the development of high-speed welding robots has advanced recently and the use of lightweight spot-welding guns has improved work efficiency. Examples were reported of countermeasures for the increasing number of locations that require spot welding. The number of robots necessary for welding work was minimized by the development of high-speed welding guns and increasing the number of welding spots per hour. Robots were also made smaller and arranged more closely together to reduce capital investment and improve space efficiency.

Materials used for exterior panels are increasingly being replaced with non-ferrous materials. This is now going beyond conventional aluminum materials to include plastic doors and fenders. Some vehicles also use plastics for both body panels and main body structural components. Some aluminum/steel hybrid parts have been developed and joined using friction stir welding (FSW). Choosing the optimal joining method for steel sheet parts is necessary from the standpoints of both cost and efficiency. In particular, there are increasing demands to make wider use of adhesives and, in the future, research will focus on improving the performance of adhesives in regard to strain and aging due to differences in linear expansion coefficients.

In addition to conventional high speed welding applications, laser welding has also being adopted for supplemental welding after spot welding. The use of additional laser welds shortens the joint pitch and improves joint strength, which makes it possible to increase the torsional stiffness of the body. Furthermore, some automakers have begun applying this technique with spot welding instead of laser welding, so this will be a trend to watch in the future.

2. 3. Plastic molding

The main requirements for plastic molding are weight reduction, lower environmental impact, and improved textures.

Reducing weight enables the use of less energy during the manufacturing process due to the smaller amount of material used, and also helps to lower CO_2 emissions during use by improving the vehicle fuel efficiency. In recent years, the use of thinner parts, materials with low specific gravity, and foam molding have helped to reduce weight even further. Plastics are actively being used as replacements for metals and glass.

Thinner plastic vehicle bumpers and instrument panels have been achieved by striking a balance between a high stiffness and impact resistance, and by improving the fluidity of the plastic during molding. This has also helped to reduce both weight and cost. Foam molding is now not only used for hidden parts, but has increasingly been adopted for visible parts, such as the engine cover and interior trim, as quality control technologies for product surfaces have advanced. In many cases, plastics have replaced other materials usually used for body parts, such as the fenders, back doors, and quarter glass. Plastics are also being increasingly used in locations with high performance requirements, such as around the engine, the oil pan, and the engine mountings.

Issues caused by replacing other materials with plastics include higher cost and part dimensional stability. An advantage of plastics is the flexibility to mold these materials into various shapes, including integrating multiple parts together into a single piece. This modularization of parts helps to reduce total costs. The corrosion resistant properties of plastics can also help minimize costs since surface treatment processes can be omitted. The dimensional stability of plastic parts can be addressed by developing materials with small linear expansion coefficients and advancing the development of long fibers that help to improve strength. These and other developments are keenly expected in the future. The use of plastics for exterior panels raises issues such as proper color matching with the rest of the body and warping. However, these can be addressed through innovations in manufacturing methods, materials, and product designs. Warping, in particular, is a problem specific to plastic molding and improvements in molding technology and simulation technology will be necessary to ensure that the quality of the alignment between plastic panels is equal to that of sheet metal panels.

CFRP is still very expensive, but productivity should increase as manufacturing processes improve, and costs should also come down as quality improves. The application of this material from race cars and some luxury sports cars to the hoods and trunk lids of regular mass-production vehicles is accelerating. A large-scale production plant has begun operating in Europe that produces vehicles with many CFRP parts. Furthermore, carbon fiber reinforced thermoplastics (CFRTPs), i.e., CFRP that uses thermoplastic, are being actively developed due to its advantages over other plastics in terms of formability and recyclability. However, there are still many issues with this material and processing methods, such as improving flowability and warping.

Opportunities to use the keyword "sustainable" have increased as various automakers have looked for ways to reduce the environmental impact of plastic parts. There is growing demand for plastic part development that consciously reduces CO_2 emissions and promotes recyclability throughout the product lifecycle, from production, to use, and disposal. Specifically, these solutions entail conserving energy by running molding machinery on electricity, reducing the output of volatile organic compounds (VOCs) by using paint-less processes, and promoting recycling of post-consumer materials.

To improve the texture of plastics, technologies must be improved to create more decorative designs, but at a lower cost. The appearance of the product's surface is an important element that helps to prompt the consumer to make a purchase. However, secondary decoration of surfaces generally adds to the cost and its application on lower-priced vehicles has not been a priority. However, improved appearance has become more desirable even on lower-priced vehicles, so new materials are being developed and new molding methods are being researched. Materials are now being developed with shiny metallic finishes and bright colors even without being painted. These have been adopted on many vehicles. It was also found that careful temperature control of dies can help to eliminate flaws in external appearance during molding. This has expanded research into in-mold decoration technologies that allow the addition of decorative patterns within the die. In addition, by researching the mechanism of touch as well sight to generate a sense of quality, grains have been developed that create a feeling of softness and low gloss. It is likely that such decorative technologies will be further developed.

In the future, as the body comes to be composed of multiple materials, technologies related to materials, processing, die, analysis, and design will accumulate at an even greater pace than ever before. Automakers will then be expected to develop further low-cost and high-quality products.

2.4. Paint

As global environmental awareness increases every year, automakers are making greater efforts to further reduce the amounts of VOC and CO_2 emissions from painting plants. At the same time, paint is playing a greater role in offering consumers appealing products.

Progress has been made in reducing VOC emissions by constructing environmentally friendly painting plants. In terms of materials, solvents usage has been reduced by adopting waterborne paints and high solid paints. Painting facilities and equipment have been improved by promoting the collection of solvents via waste-liquid recovery devices and solvent usage has been reduced by improving painting machines. Painting processes and methods have been improved by setting high coating efficiency painting conditions and optimizing robot paint sprayer programs. These also helped to further reduce solvent usage.

There is more room to reduce CO_2 than VOC emissions. This is because the switch to waterborne paints to reduce VOC emissions has actually increased energy usage compared to solvent-based paints. Consequently, efforts are now underway to reduce fuel and electricity usage. A painting plant heats large amounts of air through drying furnaces and painting booths. To reduce fuel usage, it will be important to construct painting plants heat less air and that can reuse the energy contained in the air that is heated.

One way of building a painting plant that heats less air is to integrate the primer and top coat functions into a single process and then to eliminate the primer drying furnace. If waterborne paints are used on this integrated painting process line, a heating zone between the primer and top coat base coating is necessary. However, improved painting materials have led to technologies that make this extra heating unnecessary. Furthermore, additional improvements in painting processes and materials have eliminated the sealer drying furnace, and the number of drying furnaces used in painting plants has dropped to one-half that used in the past. Painting booths have also become more compact as the number of painting robots has been reduced and robot installation methods have improved. This in turn, has led to a major reduction in the volume of air required for the painting booths.

The collection and recovery of heat from drying furnaces is being adopted as a means of reusing energy in heated air. The switch to automated painting booths is promoting the recycling of emissions. In the future, in addition to paint, bake-hardened steel sheets and body sealers will also be baked at lower temperatures to help advance the construction of painting plants that require less heat.

In recent years, improvements in vehicle design, such as the application of very bright and intense paint colors and an increase in two-tone vehicles, have accelerated to enhance product appeal. The development of scratch and stain resistant paints is also increasing. These advances help to improve the quality of the external appearance while contributing to fuel efficiency by reducing vehicle weight. Consequently, efforts are being made to lower the specific gravity of high viscosity paints, such as sealers and undercoats. As plastics are increasingly being used instead of steel, color matching technologies are also becoming more important.

2.5. Vehicle assembly

A key point in the vehicle assembly process that determines the competitiveness of an automaker is how to improve productivity and quality despite massive changes in markets inside and outside Japan. In the Japanese vehicle market, automakers are responding to changes in production volume, the decreasing labor force, aging population, and a higher ratio of women on the shop floor. Vehicle production equipment must respond flexibly to changes in production volume and also reduce the amount of heavy manual labor. Markets outside Japan continue to expand thanks to demand in emerging nations, giving rise to issues such as meeting increased demand in a short period of time and maintaining quality. Efforts to address these issues are ongoing. Vehicle body structures are also changing in response to added safety requirements, such as collision damage mitigation, and the adoption of weight reduction technologies, such as the increased use of plastics, CFRP, and less wiring. Responding to these new technologies creates new challenges, such as establishing manufacturing technologies and ensuring quality. Efforts are underway from both the production equipment-side and the body structure-side to minimize preparation times and cost to meet these challenges.

Body structures are being changed in various ways to help reduce the cost of parts. These include the standardization of vehicle platforms and the sharing of common functional parts to streamline and simplify production equipment. Assembly parts are increasingly being modularized to help reduce the work hours needed for installation and improve the work-hour balance of the main assembly line. As more safety functions are installed on vehicles, these functions must be inspected and adjusted on the assembly line. The transmission function of on-board controllers is being utilized to help handle this within production tact times. Every automaker is undertaking various initiatives and strategies to develop body structures that are both lightweight and ensure external appearance quality.

Automakers are promoting the establishment of production lines that can respond flexibly to market demands and are implementing various innovations to adjust production capacity in a short amount of time. In Japanese vehicle plants there is an urgent need to reduce the amount of heavy manual labor to address the aging of the labor force and the growing percentage of women on the shop floor. Consequently, devices that assist workers with the installation of heavy parts have been introduced and high-torque tightening work has been automated. As production equipment can become a bottleneck when the number of work processes is increased or decreased, technologies are being developed to allow both people and robots to coexist on the production line and maintain the line balance flexibility. The main production line is subjected to leveling (***heijunka***) and differences in work hours are absorbed on sub-lines to promote better efficiency of mixed production. In plants outside Japan, the biggest issue is how to ensure quality with a relatively unstable labor force. This has led some manufacturers to introduce devices that help to prevent human error (kit supply systems) and also to automate quality inspections.

In the future, an easier working environment will be necessary to cope with changes in the labor force. Body structures will be evaluated using 3D data and simulations from the early stages of model development to help ensure assembly workability and to check work postures. These kinds of body structure reviews will be used to improve the ease of assembly. Other new technologies are also being developed to improve the work postures of production equipment and reduce the amount of heavy manual labor that is required.

3 Powertrain PE Technologies

3. 1. Casting

Digital engineering is being used to improve the efficiency of product development processes for castings, thereby shortening the development period. Computer-aided engineering (CAE) technology with a focus on casting analysis has also been introduced and its accuracy improved to promote frontloading (i.e., putting more emphasis on studies in upstream processes). This has greatly reduced the total number of development work hours before mass production, and allows the introduction of products that accurately and quickly reflect the changing needs of the market. The utilization of 3D printers as a derivational technology is also expected to contribute to the field of casting. Metal dies in unconventional forms may be realized using metal melting and forming methods via lasers and electron beams that use 3D laminating technology.

In contrast, the reduction of weight has become a high hurdle for castings. Significant reductions in weight are not easy to achieve with existing materials and manufacturing methods. Therefore, in many cases, the only conventional means of accomplishing this was to adopt other materials and manufacturing methods. Technology that forms super-thin die cast products using ultra-high speed injection has entered mass production thanks to improvements in casting design and high-vacuum environments, as well as optimization of product shapes. There are also examples of a low-pressure casting method being used to manufacture thin cylinder heads by changing to a stokeless furnace. Using water to cool dies has also helped to shorten the cycle time and improved productivity. In the case of cast iron products, a case was reported in which a conventional cast iron cylinder block was replaced with compacted vermicular (CV) cast iron that has the same level of strength but reduced thicknesses and weight.

Cast iron is inexpensive and is the main raw material used for automotive steel sheets. The amount of manganese contained in these steel sheets is increasing as the automotive industry moves toward the use of more high-tensile steel. However, since it is difficult to use manganese in ferritic ductile cast iron that requires toughness, a switch to more expensive raw materials, such as pig iron, was unavoidable. This has become a serious problem and the industry is anxiously awaiting the establishment of a treatment method that does not require manganese.

The environment surrounding casting in Japan in severe and there are numerous problems, such as high energy and raw material costs. However, casting also contributes greatly to improved engine performance. For example, cast iron sleeve liners have been adopted in aluminum engine blocks using centrifugal casting and a molding coating method to create protruding surface shapes. This method has been adopted by almost all automakers. It is an example of how a unique technology can be added to a conventional manufacturing method, creating new casting methods and parts. There is no doubt that this will become an important factor for maintaining casting processes in Japan.

3. 2. Forging

Reducing CO_2 emissions during manufacturing has come to be regarded as an important issue from the viewpoint of protecting the global environment. The adoption of cold forging in place of hot forging is just one example of this. Cold forging has also been applied to medium-sized parts that have a comparatively large amount of deformation, such as in the suspension. Cold forging has other advantages, including high strength, precision, and yields.

Running in parallel with these trends are continuing efforts to reduce weight and create forged parts with net-like shapes. The split-flow forming method of forming gear teeth profiles has now been adopted as a common method of manufacturing highly precise gear teeth, and it has also become possible to form gear teeth with crowning by using the elastic deformation of the die. It is difficult to switch over to more lightweight materials for shaft parts, but hollow parts have been practically adopted. It may also be possible to achieve significant weight reductions by using cavities with different diameters.

It is well-known that the formability, forming load, and service life of a die are strongly affected by the processing speed. These can be controlled through the use of a servo press. The digitalization of optimization technologies and integrated processing controls is continuing to advance in conjunction with the improved precision of CAE simulation analysis.

Research into steel for forging is shifting toward obtaining optimum hardening characteristics for the various surface hardening treatments. In the case of the case-hardened steel that is used for most gears, a shift has occurred from alloy design assuming conventional gas carburizing treatment to a diversity of design requirements for many different potential treatments, such as soft nitriding, carbonitriding, vacuum carburizing, and high-concentration carburizing. The rising cost of alloys and supply problems have also caused a shift toward the use of designs with fewer alloying elements, such as case-hardened steel with no nickel or molybdenum and vanadium-free untempered steel. The development of new technologies is advancing through the combination of heat treatment and materials technologies to maintain and improve the strength and durability of steel.

3. 3. Heat treatment

The purpose of heat treatment is to secure parts with the required properties by heating and cooling metal. This technology is indispensable to automotive part production, especially drivetrain parts. Vehicle development and production has changed in recent years as concern for the global environment has increased. Reducing body weight and part sizes parts has become more important than ever to help improve fuel efficiency and reduce CO_2 emissions. Efforts are underway to help make heat treatment more energy efficient and less harmful to the environment, while also increasing the strength of steel with high precision.

Carburizing and quenching is the mainstream conventional form of heat treatment, and continuous gas carburizing and quenching has been adopted for mass production and low-cost production. However, more manufacturers are switching to cell-type vacuum carburizing and quenching because it uses less gas, is more environmentally friendly, and is better at handling small lots of multiple products. The spread of vacuum carburizing is also accelerating. This method allows fast carburizing while suppressing the coarsening of crystal grains through innovations in materials and quenching methods. Productivity can also be increased without impairing impact strength. An atmospheric control sensor for vacuum carburizing is also being developed, and this method of carburizing is expected to expand even further in the future.

The strain of carburizing and quenching cannot eliminate the effects of residual stress from previous processes, its own weight, the thermal stress of heat treatment, and structural transformation. Technologies to minimize strain are required and the development of a cooling agent with cooling characteristics equal to those of molten salt is essential. The combination of high-frequency re-heating and quenching with a single-stage jig and high-pressure gas cooling is also being developed. It will be important to adopt this technology in accordance with the purpose of the part.

Another technology with good sliding performance and good resistance to high surface pressure was developed for the soft nitriding treatment that is often applied to parts such as crankshafts. This was accomplished by salt-bath nitrocarburizing, in which the oxide film and compound layer form at the same time, since it enables excellent sliding properties, as well as a combination of salt-bath nitrocarburizing and induction hardening.

The combination of various surface treatments is being advanced to achieve high-performance parts with good wear resistance and a low coefficient of friction. One such treatment is diamond-like-carbon (DLC), which is being promoted for a variety of different products. Adhesion is quite important and is affected by the structure and hardness of the surface treatment. Therefore, it is necessary to select a DLC manufacturing method that is suitable for surface treatment.

Research into simulation technologies is also making progress and it is now becoming possible to carry out process design without trials by simulating the quality of the heat treatment (such as the strain, profile of hardened layer, and residual stress). In some cases, this has been introduced in a set along with vacuum carburizing equipment and adopted by some manufacturers for gas carburizing and nitriding. Furthermore, the development of software capable of considering individual differences in each piece of equipment (such as the amount of strain that changes slightly due to individual differences in equipment), may enable production that also helps to ensure heat treatment quality. For many years, heat treatment processes have relied on the experience and intuition of skilled workers at the plants. Now, plants are starting to move toward a production system in which younger workers with less experience can also ensure product quality.

3. 4. Machining

New power sources, such as batteries and motors in electric vehicles (EVs), are emerging in response to increasing demands to reduce the burden on the global environment. However, internal combustion engines still have a large role to play and must to continue to evolve. Demands for better driveability and dynamic performance, as well as for better fuel efficiency are increasing, making it more and more important to simultaneously achieve both of these performance aspects. Downsized engines equipped with turbochargers are now a mainstream means of improving combustion efficiency and reducing mechanical loss. Even in Japan, there is increasing interest and focus on clean diesel engines. Various new mechanisms have also been added to the engine to better control the intake and exhaust system.

Machining processes must be compatible with materials that are difficult to machine due to super finishing processes and additional surface treatments, as well as high strength, high hardness, and high stiffness materials that have been subjected to hardening treatments. Production systems have shifted to small-lot, multiple product production as the number of engine variations has increased, the service life of engines has become shorter, and to comply with engine specifications for different countries. Consequently, each company is implementing initiatives such as those shown below.

(1)Reduction and dispersion of the scale of the production line (200,000 vehicles/year to 100,000 vehicles/year to 50,000 vehicles/year)

(2)Standardization (processes, equipment, jigs)

(3)General purpose lines and machines (no set-up, single set-up)

(4)Process consolidation (reduction of jig types)

In terms of quality, contamination standards have become stricter due to the addition of devices to improve fuel efficiency. In response to demands for greater cleaning process functions and the higher quality, there is a growing need for quality information management, such as the automated inspection of all vehicles using laser measurement and video image measurement, various forms of traceability, and data storage. There is also a need to increase the functionality of other production equipment as well as processing machines. In the past, the strategy was to develop engines in Japan before deployment in plants outside Japan. This strategy is now shifting to the direct local development and production of engines. This requires the simultaneous deployment of production equipment that is simple and stable for use in any country. It may also be necessary to identify new formats for production lines located only outside Japan.

Pre-engineering is an increasingly important part of the development of new machining technologies. This includes cutting simulations and stiffness analyses that are achieved through the development of new CAE technologies.

3. 5. Powertrain assembly

As demand for environmentally friendly vehicles increases, the number of powertrain variations, such as fuel cell vehicles (FCV), hybrid vehicles, and EVs, also has expanded. Automakers must now be able to respond flexibly to a variety of different orders at a low cost, as well as to large fluctuations in production volume. Assembly lines that are compatible with these new demands have been incorporated into production systems based on the concepts of small volume production of multiple units and varying volume production of various units.

Compact assembly lines are built on an idea different from the conventional concept of reducing cost by volume production. A compact assembly line is a small-scale production line capable of minimizing manufacturing costs even with small production volumes. Conventional production lines are mainly composed of specialized equipment tailored to limited product shapes. These were intended as mass-production lines composed of many automated machines and multiple rows of processes. These lines require large-scale equipment changes and long production preparation periods when switching to another product, which makes it difficult to respond to fluctuations in volume. These issues can be resolved by reducing the number of pieces of equipment through integrating processes, simplifying and streamlining equipment, and promoting the miniaturization of both general purpose and specialized equipment.

Production on an even smaller scale is often handled through cell production systems with a variety of different forms, such as standalone systems, split cell systems, and relay systems. In unit assembly, modules that combine multiple parts are assembled in cells and then these modules are supplied to the main processes for further assembly. This allows small volume production of multiple units.

Cooperative robots will be a key basic assembly technology to enhance the general-purpose nature of equipment. Currently, only fully automated robots have been adopted since humans cannot intervene when robots are used. Robots also cannot be adopted without making full use of vision sensors, and require high-performance work, part positioning, and part dimension accuracy. Robots also tend to boost equipment costs. However, if robots could work cooperatively with humans on the assembly line, workers could position work correctly and allow the robot to handle the other work. This would expand the range of robot applications and enable the creation of effective semi-automated processes.

Assembly lines are being developed that can quickly and flexibly add or change production in response to market demands and that can be deployed quickly outside Japan. Realizing this type of production system will require efforts from the PE-side and the integration of development and production divisions. The fundamental innovation of manufacturing for the future will be of critical importance.

4 CAD/CAM/CAE

To address the challenges of shortening development periods, improving quality, and reducing vehicle cost, PE divisions must utilize CAD, CAM, and CAE for parallel development from the product design stage.

During the design stage (before drawing release), CAD data from the latest product being designed is increasingly being used to perform CAE analysis of processing technologies, including stamping formability, welding strain, and electrodeposition paint throwing. This speeds up the return of design requirements to the design divisions. Product CAD data is linked with equipment data to form a virtual factory, thereby enabling an equipment capacity simulation. This also makes it possible to verify that the plant layout, material logistics, and production volume per hour is optimized before mass-production begins. In addition, this data can also be deployed in assembly work simulations, and improvements to facilitate assembly can now be integrated with product CAD data.

The utilization of 3D non-contact measuring machines is being promoted during the prototyping stage (after drawing release). The surface measurements obtained by these machines make it possible to identify differences between the CAD data and product, check the reproducibility of the design, understand changes in state between processing steps, and clarify the causes of any quality problems at an early stage. Part scanning data allows parts to be assembled on a computer and then the dimensions of each part can be adjusted to within the necessary tolerances. If this method is used, then it is expected that the quality improvement work, which requires special skills and sometimes becomes a problem during model preparation outside Japan, could be carried out remotely in Japan by engineers analyzing measurement data from the local plant. 3D non-contact measuring technology is not limited to product measurement. It can also be utilized for reproducing items through reverse engineering after completing adjustment work for stamping dies, and is useful for making copies of items deployed outside Japan.

In the time between product design and manufacturing, information associated with the product CAD data is scattered across every division. By tying the process information, such as dies and jigs, equipment, work procedures, and measurement results, to the product CAD data, every division involved in vehicle development will always be sharing the latest data. This will allow the accumulation of know-how obtained during conventional vehicle development. This type of environment will be crucial to achieve even higher QCD targets.