Production Technology and Production Systems

1 Introduction

Overall global vehicle sales in 2014 reached approximately 88 million vehicles, significantly higher than the level in 2007 before the financial crisis, in which approximately 71.5 million vehicles were sold. However, the Chinese market accounted for the largest portion of this increase in sales and, even though a record number of new vehicles were sold in China in 2014, the growth rate of the market in China was lower than that of the previous year and appears to be slowing down. In the near future, the adoption of even more stringent emissions and fuel economy regulations is predicted to lower this growth rate even further. There also appears to be little reason to be optimistic about growth in any of the other global vehicle markets. In Japan, the market reached its peak in 2006, when some 5.56 million new vehicles were sold, but since then the consumption tax has been increased and sales of standard-sized vehicles have slowed as consumers increasingly shifted to purchasing mini-vehicles. The market in Japan is expected to continue to shrink in the future due to higher taxes on mini-vehicles and stricter criteria to qualify for the tax reduction for environmentally friendly vehicles. Given these circumstances, the entire automotive industry in Japan is rushing to find ways to not only make vehicles more environmentally friendly and safer, but also to tackle new issues such as the aging population and decreasing interest in vehicles by young people. Production engineers must aim to realize innovative new production engineering mechanisms and designs to build even safer and more appealing vehicles. This is increasing the demand for even further improvements in the technical skills of these engineers.

2 Vehicle Production Engineering (PE) Technologies

2. 1. Stamping

In recent years, the application of high-strength steel sheets to various vehicle body parts has been expanded to improve fuel efficiency and collision safety. High-strength steel sheets in the 980 MPa class and higher are being adopted in vehicle frame parts and 440 MPa class steel sheets are being adopted in exterior styling panels. Consequently, finding ways to improve forming and shaping technologies so that these high-strength steel sheets can be formed into various new shapes is becoming an urgent task. In the case of luxury vehicles and some more common passenger vehicles, there has been increased use of aluminum and even examples where steel has been replaced with plastic. As a result, improving production efficiency has also become an issue for automakers.

As described above, high-strength steel sheets are increasingly being employed for use in vehicle frame parts. These sheets are often formed through cold stamping into both simple shapes and T-shaped and L-shaped forms to increase stiffness. Even 1,200 MPa class steel is increasingly being used for frame members. Springback deformation is a major issue for high-strength steel sheets. Measures to address this issue, as well as product shapes, innovations of processing methods, and formability prediction techniques are all advancing in conjunction with other improvements in mold surface treatment techniques.

The hot stamping method of forming steel sheets was developed to solve problems associated with cold stamping, such as formability and ensuring dimensional accuracy. In hot stamping, the heated material is held in a molded state and then cooled and quenched (forced into martensitic transformation). This method makes it possible to give the finished material strength characteristics that are higher than the inherent material strength. In fact, hot stamping has made it possible to obtain steel with 1,500 MPa-class strength and its use in vehicles has expanded rapidly in recent years. As a result, there is now great demand to improve the productivity of this steel for use in mass production vehicle assembly lines. Shortening the heating and cooling times for this material is directly connected to the cycle time, so ways to reduce these times are being actively developed. One specific disadvantage of hot stamping is the possibility of delayed fracturing during trimming after quenching. Currently, the most common way of preventing this fracturing is to use a laser cutter. The trimming process must be improved in the near future to expand the number and types of parts using this very high-strength steel.

Aluminum material has poor formability, but it has a specific gravity that is 65% lighter than steel and its tensile strength and yield strength are equivalent to those of mild steel plate. Consequently, it has started being applied to the entire vehicle frame in recent years. It is also becoming common to see aluminum used for various closure parts and covers on mid-size vehicles.

Finding a way to reduce the cost of stamping is becoming an important issue as new materials are increasingly adopted under the design philosophy of using the appropriate material in the appropriate place. Cost reduction activities are being implemented that consider the optimization of the entire vehicle. These activities include improving yields by optimizing the shape of excess material at the time of forming, using shapes that optimize the yield through coordination with the product design divisions, proposing boundary locations, and making effective use of secondary materials. In addition, other efforts are being made to improve the overall efficiency of die creation (cost reduction). These include advances in die strength analysis and measurement techniques and the active use of surface strain prediction technologies and dimensional accuracy prediction technologies.

2. 2. Welding

The structures of vehicle bodies are constantly being designed to be lighter to help satisfy the demands for improved fuel efficiency and environmental friendliness. At the same time, other efforts are being made to also improve the appeal of vehicles by offering greater collision safety, superior handling and stability, and a more comfortable ride.

More vehicle structures are adopting multiple different materials to help reduce vehicle weight. Non-ferrous materials, such as aluminum alloys, carbon fiber reinforced plastic (CFRP), and plastic are increasingly being adopted in place of steel and new techniques are being developed to join these different types of materials together. The development of new aluminum alloys with higher levels of strength has advanced and these materials are starting to be adopted more widely for use in frame parts. To join these alloys to steel sheets, techniques such as friction stir welding (FSW) and the application of rivet-like items have been adopted and used on mass production vehicles. CFRP is used on the outer panels of expensive luxury vehicles, but it is also now being added to critical portions such as pillars as a reinforcing member. In addition to the use of adhesives to join CFRP to steel sheets, another joining technique that uses a laser has also been announced. Technological development has advanced to the point that a strong enough bond can be generated that breakages occur from the base material rather than the joint surface. Plastic outer panel parts are now frequently used to reduce weight and improve formability. These panels are then bolted to steel sheet body frame members. This localized use of plastic parts has also been adopted on lower cost, mini-, and compact vehicles.

Innovations in the manufacture of steel material continue to advance as steel sheets become ever thinner and high-strength steel sheets become ever stronger. The usage ratio of hot stampings also continues to increase, mainly for vehicle frame parts. The relative sheet thickness ratio (the ratio of the total sheet thickness to the thinnest sheet in a lap weld) has been increasing for a long time, which has made spot welding more difficult to perform successfully. Consequently, new techniques have been developed, such as up-slope electric current supply and multi-stage current supply to help control the current supply time and cycle, and new welding methods, such as laser welding are being adopted in place of spot welding. The technological development of electric current control during welding has made it possible to weld high-strength steel sheets even with the manual welding equipment often used in emerging markets. The number of welding points is also increasing to help ensure the stiffness of the vehicle body. Automakers are also facing demands to shorten vehicle production lines. The use of high-speed welding robots and welding guns, as well as densely arranged small-sized welding robots has helped to shorten the time for the welding processes on these lines.

As the use of high-strength steel sheets has expanded, it has become necessary to develop new welding techniques and to develop new methods of inspecting weld quality. One common method used to check the quality of spot welds was the cold chisel test, but driving a chisel into the spot welded portion of high-strength steel sheet may cause cracks to form in the nugget and decrease the weld strength. For this reason, non-destructive weld inspection methods, such as using ultrasonic waves or the principle of transmission and reflection of laser light, have now been put into practical use in place of the cold chisel test.

2.3. Plastic molding

In recent years plastic molding has come to be used to reduce the weight of body parts and to help meet the demands for improved texture, feel, and appearance of interior parts. Various new techniques and technologies have been developed to reduce overall vehicle weight, thereby lowering the amount of materials used, improving fuel efficiency, and reducing CO_2 emissions. In the past, outer panel parts, such as the back doors, were often made from steel, but these have increasingly been replaced with plastic. Even parts such as bumpers and interior parts that have usually been made from plastic are becoming lighter thanks to new innovations in the manufacturing techniques for plastic parts.

The driving force behind the continuing switch from steel to plastic has been the growing need for major reductions in vehicle weight. Plastic has been adopted for use in the back doors, fenders, and even some engine parts. CFRP is expensive, but it is also strong and lightweight, resulting in its use in the roofs and body frames of some commercially available vehicles. In the past, since plastic was not superior to steel in terms of cost, use was limited to outer panel parts such as bumpers. More recently however, automotive designs are assuming the use of plastic materials, and there is increasing use of plastic materials to leverage the inherent advantages of this material. At the same time, the use of plastic materials in vehicles has some troubling issues that need to be addressed, such as deformation and warping due to shrinkage of the material and color matching with the vehicle body.

Molding plastic vehicle parts such as bumpers and instrument panels using multipoint gate injection reduces part thickness. This is now a mainstream weight reduction technique. There is some concern that the appearance of plastic parts may deteriorate due to the presence of weld lines or weld marks when molded using multipoint gate injection. However, as the accuracy of plastic flow analysis has advanced, the use of simulations to help determine the gate positions and injection timing in advance has been able to restrict this issue to a manageable level. In the U.S. and Europe, foam molding of plastic has become a mainstream technique. There are two types of foam molding: chemical foaming and physical foaming. In chemical foaming, a foaming agent is mixed into the plastic. This agent then releases gas during the molding process and very small pockets of space are formed within the plastic. In physical foaming, nitrogen and carbon dioxide gases are injected into the plastic while it is within the screw of the molding machine. These gases are then released into the plastic and very small pockets of space are formed within the material. In addition to weight reduction, physical foaming methods also possess superior dimensional stability characteristics.

To improve the appearance of plastic interior parts, some metal dies for these parts are processed to have fine graining that give the design surface of the plastic parts a low-gloss finish or even imitate the look of a thread seam (stitching). Another trend is an increasing use of decoration on interior parts to match the upmarket tastes of many users. This includes the use of piano black tone and metallic plating on interior parts. Some vehicles are equipped with instrument panels that are made from molded polypropylene (PP) as the base material, but then given an urethane outer skin to give it a nicer, more luxurious feel that is softer to the touch. Various other styles and techniques are also being used to make plastic interior parts look and feel higher in quality. These include such examples as using an actual thread to give the plastic the appearance of a thread seam and using a carbon fiber tone or geometric pattern on the surface of the plastic instead of just imitating a leather pattern.

As the demand to make more and more parts out of plastic continues to gather speed, the development of new plastic materials, processing techniques, die technologies, analysis technologies, and design techniques will also continue to advance to enable automakers to develop more low-cost, high-quality products.

2.4. Paint

In recent years, high intensity paint colors have often been used as the image color for vehicle models and companies to appeal to customers. There has also been increasing demand for highly decorative paints, such as the abundance of two-tone paint schemes being adopted on mini-vehicles. In the future, it is thought that new designs will continue to be adopted, such as matte finish and metallic paints. Plastic materials are being adopted in place of steel for outer panels in more cases to reduce weight. Therefore, painting methods that suit the characteristics of these materials are also being adopted. The environmental performance of vehicles is increasing in importance to consumers. Therefore, the reduction of compounds that have a large impact on the environment during the painting process, such as volatile organic compounds (VOCs) and CO_2 emissions, is becoming an important theme when the life cycle assessment (LCA) of the vehicle is considered.

A common approach to reduce VOC emissions from painting is to improve the materials, improve the yield, and then control the emissions from the painting system through collection and aftertreatment. To this end, significant improvements have been made to the vehicle painting process by implementing countermeasures such as adopting waterborne paints and high solid paints, setting high coating efficiency painting conditions, optimizing robotic paint sprayer programs, collecting waste paint thinner, and treating painting process emissions.

Several individual approaches are being used to reduce CO_2 emissions from painting. These include reducing the number of painting processes, making the equipment and processes more compact, selecting and changing the energy and heat sources, and collecting and recycling waste heat. In addition, other methods are addressing this issue on a plant-wide scale through the proper placement of heat sources and using sufficient insulation.

Some concrete examples painting process reduction are as follows. The surface conditioning process has been eliminated by employing a zirconium oxide chemical conversion coating agent during pre-treatment, sealer drying furnaces have been eliminated, and the 3-wet painting process that eliminates the baking process after the primer is applied has been widely adopted by many manufacturers. An even more advanced and shorter version of the 3-wet painting process, in which the preheating is also eliminated, is now also starting to be adopted by some automakers.

Outside Japan, it has already become common to reduce the size of equipment and processes by adopting a rotating transporter for auto bodies to proceed from pre-treatment to electrodeposition. This kind of painting process arrangement has also begun to be adopted in Japan. In more cases, underbody spray coating has been replaced with slit coating to eliminate air supply and discharge processes. The increasing use of robotic sprayers to apply the primer and top coats, as well as optimizing the arrangement of these robots, has allowed automakers to reduce both the size of the painting booths and also the amount of exhaust air that is produced.

Some manufacturers are attempting to reduce energy usage and heat sources by shifting from a centralized arrangement to the individual arrangement of secondary energy sources that suffer large energy losses during transport, such as steam and compressed air. Others are adopting alternative painting methods that do not require any air. Another method being adopted to reduce the amount of waste heat is to expand the use of heat pumps and enable simultaneous use of hot and cold air.

Finally, some manufacturers are collecting and recycling waste heat by expanding the automation of interior sheet painting, such as the door opening during primer and top coat applications, reducing the pressure loss of the painting booths, and introducing systems that recycle supplied air to reduce the energy required for air conditioning. The humidity must be removed by a water-washing scrubber to recycle the supplied air, but some non-Japanese manufacturers have already introduced recycling booths that do not require dehumidification thanks to a common dry scrubber that uses calcium carbonate.

In addition to the heat sources produced within vehicle painting plants, changes in seasons are also a factor in the use of energy for air conditioning. To reduce this energy usage, heat sources can be placed in appropriate locations within the plant and facilities, and the equipment, and outer walls of the building can all be properly insulated to help reduce energy consumption. It is expected that these common sense solutions will be adopted in the future.

2.5. Vehicle assembly

Vehicle assembly is composed of a variety of elements, such as part selection, tightening, fitting, adhesion, oil and water injections, insertion, and checking. Almost all of these processes are dependent on a human touch by a trained assembly line worker. Consequently, creating assembly processes that are easy for workers to perform is essential to improving the quality and productivity of the assembly line.

In Japan the population continues to be shaped by an aging society and a falling birth rate. Consequently, it has become necessary to find a way to involve a larger number of older people and women in the workforce to help ensure a sufficient amount of labor. This means making further improvements to burdensome work that requires heavy labor and/or difficult postures. In other countries as well, the need to improve the retention rate of workers has become an important issue to help ensure a stable level of quality in vehicle manufacturing, and a growing number of people are calling for improvements in the working environment. At the same time, the number of vehicles that are being produced is fluctuating wildly both inside and outside Japan. This means that manufacturers are looking for ways to ensure flexible production and maintain consistent operation through measures such as mixed-product production, line changes, and takt time adjustments, and the like

Typical countermeasures for these issues include work leveling (heijunka) and the use of common parts and vehicle structures that transcend vehicle segments or through modularization, which completes certain functions on sub-lines so that the workers can be in more normal postures during the assembly processes. Work leveling also helps to even out major differences in work hours between different sections. The assembly facilities and equipment are also being examined and changed to help ensure more flexible responses to production volume fluctuations. For example, equipment is being developed that is relatively simple, small in size, and easy to move in the event of process reorganization. More manufacturers are also adopting worker-friendly assembly processes by improving the working posture, providing assistance to lift and move heavy objects, and automating tightening work that requires high torques to be applied. The development of assembly line robots that can coexist and work alongside human workers is also advancing.

As explained previously in this article, there are now many examples of how the structures of the vehicles are being changed to reduce weight, increase fuel efficiency, and enhance collision safety through the use of outer panels and other parts made from non-ferrous materials such as CFRP and plastic. In the near future it will be important to develop fitting structures that take into consideration the particular stretching and warping characteristics of plastic, and to develop technologies that can handle the adhesion strain caused by differences in the coefficient of expansion to carry out mass production at low cost. As more vehicles are equipped with driving support technologies such as collision prevention safety devices, initiatives are being promoted to ensure the functionality of such devices through initial adjustments and inspections. Furthermore, 3D data is being utilized from the initial stages of vehicle development to enhance workability and equipment verification, with the aim of reducing both development periods and costs. The use of 3D printers and other digital tools to advance the confirmation phase will also be important

Finally, the scale of redesigns and improvements required when a malfunction occurs during the development and production processes is continuing to expand due to the greater use of common parts and the increasing number of electric functional components. Consequently, it is also becoming critical to establish clear traceability back to a large variety of different processes.

3 Powertrain Production Technologies

3.1. Casting

As competition in the mini-vehicle market grows fiercer, the casting process is an area that needs to be improved to help automakers introduce new models with good fuel efficiency and low prices in a timely manner. There are growing demands within production divisions to shorten the lead time up to mass production and to develop new technologies that will allow for the casting of even thinner materials to help reduce vehicle weight.

To shorten lead times, manufacturers are improving the degree of finish of casting molds by increasing the precision of casting CAE technologies, reducing reworking loss, and minimizing the time required to achieve quality targets. In recent years, CAE has come to be widely used on a practical level as high performance analysis software and computers have become more widely available. However, a variety of problems still remain in the ability of manufacturers to accurately predict casting defects, and this prediction technology is still developing. Particularly in the case of the die casting process, since molten metal is injected into the die at high speed and pressure, many casting defects occur as a result of the filling and solidification of this molten metal. Visualization of the casting process is therefore critical to improving prediction accuracy and clarifying the causes of defects. Consequently, manufacturers are developing measurement technologies that can directly measure the behavior of the molten metal under severe conditions and are carrying out visualization experiments using water models that approximate the actual phenomena of the molten metal. It is expected that defect prediction accuracy will be improved by incorporating the results from these verification experiments into detailed simulations.

In terms of efforts to shorten lead times for die manufacturing, die designs are being automated through the use of 3D digital tools. In addition, the dedicated portions of dies that are manufactured for each product are being minimized by standardizing the general purpose and specialized isolation structures.

Measures to improve the accuracy of CAE were discussed previously in this article. These are essential for making automotive castings even thinner to help reduce weight. At the same time, die insulation technologies such as carbon coating (a die surface treatment) have been found to be extremely effective. It is expected that the application of both molten metal injection controls and sleeve insulation will make it possible to develop ultra-thin die cast forms.

However, the current environment surrounding the casting industry in Japan is pushing up costs. The cost of imported raw materials is increasing due to the depreciation of the yen and electricity prices are also rising due to the stoppage of many of Japan's nuclear power plants. Consequently, pressure is building on the industry to find ways to cut costs even further and to also dramatically increase productivity and yield.

In low-pressure casting, a reduction of the casting takt time was achieved by using a core with good thermal conductivity and indirect water cooling of the die. In the field of die casting, cycle times were sped up by adopting surface cooling that improves the effective cooling area compared to conventional reciprocating spot cooling and the use of 3D layered manufacturing (additive manufacturing: AM) that enables new levels of cooling not previously possible using conventional methods.

Manufacturers are aiming to improve product quality and reduce the amount of defect loss by moving away from the conventional "whack-a-mole" method of dealing with problems that occur. Instead, manufacturers are beginning to implement specific activities that ascertain the production conditions that result in good quality products. These include data collection and analysis using traceability systems and attempting to quantify casting defects using high-output X-ray CT scans. These activities are just beginning, but the level of completeness of these new systems are being raised by the addition of directly measured information and the visualization of casting information that cannot be digitized. It is expected that these advances will help the casting industry to finally achieve its long-cherished desire of zero casting defects.

3. 2. Forging

Every year since the Great East Japan Earthquake, shortages of electricity have become an issue and electricity price increases are having a major impact on the costs of the forging processes. In particular, efforts to save energy and reduce CO_2 emissions have become a critical issue for hot forging since this technique requires the materials to be heated to very high temperatures inside a furnace. As manufacturers try to improve vehicle fuel efficiency and rapidly globalize vehicle production, there are growing needs for high-quality and highly precise forgings that also help to reduce vehicle weight.

The quality and precision of forged parts are improving steadily. One of the major factors contributing to this is the adoption of split-flow or back pressure forming methods for casting gears. In the case of pulse forging using a servo press, some research is examining how the addition of load vibrations can be used to disperse the heat generated during forming and keep the work temperature at a uniform level. This may also help minimize variations in the dimensions of forged gears, maintain quality, and ensure stability. In the conventional gear forging process, any errors in the gear tooth profile and pitch could be controlled via the die, but there was a problem with the accuracy of the gear tooth trace error (helix deviation). It is expected that the practical use of this pulse forging method with additional load vibrations will dramatically improve gear tooth trace accuracy, such as in the case of splines with a long axis.

A tensile load extrusion method for deep holes was developed to help reduce the weight of forged parts. This method has made it possible to carry out deep-hole forming of hollow products. Conventionally, the limit to the depth of the holes that could be formed in one process was three-times the hole diameter. However, by adding a constant load in the opposite direction from the forming direction and suppressing the buckling of the punch, it is now possible to achieve hole depths in one process that are ten times or more than the hole diameter.

The practical use of CAE in the forging industry has now entered its mature period. The analysis of the helix deviation of helical gears and shape deformation analysis have both advanced due to combining actual conditions with simulations. Furthermore, CAE is also being used to analyze die lifetimes and wear in hot forging. The future is likely to see further diversification of these analysis methods and further expansion of the applicable scopes.

3. 3. Heat treatment

Heat treatments are used to create a part with the required functionality by applying an appropriate amount of heating and cooling to the metal. This process is absolutely essential to ensuring the functionality of drivetrain parts in particular.

In the case of mass-production drivetrain parts that are treated under the same conditions, continuous gas carburizing and quenching has become the mainstream production method. This is a system that makes it possible to carry out heat treatment at a low cost. However, this system also emits high levels of CO_2 and it cannot respond very flexibly to fluctuations in production volume. Consequently, module-type vacuum carburizing furnaces have been increasingly adopted. Two major advantages of vacuum carburizing furnaces are improved product functionality due to the lack of grain boundary oxidation and shortened heat treatment time due to high-temperature carburizing. In addition, machining and heat treatment processes are increasingly being carried out at local vehicle production plants as production capabilities are transferred outside of Japan. The module-type vacuum carburizing furnaces make it easier for less experienced workers to ensure the quality of parts. Therefore, heat treatment systems that use these furnaces are increasingly being adopted all around the world.

Other heat treatment methods are also popular and are being adopted in accordance with the various different quality requirements of the parts. These treatment methods include induction hardening, gas soft nitriding, and carbonitriding. Recent years have also seen increasing use of surface treatments that utilize plasma, lasers, and even electron beams, as well as hybrid heat treatment methods that use combinations of several of these methods. In Europe, since there are fewer restrictions on the use of high-pressure gas, gas cooling is often adopted in the cooling process to reduce the amount of variation caused by strain and distortion during quenching.

Technological development is making progress in the field of heat treatment simulation and the accuracy of calculations is being improved to help determine the optimal treatment conditions necessary for the required product quality. The use of actual test treatments is also helping to reduce the number of quality confirmation cycles. In the future, the aim is to incorporate the heat treatment process into the machining line. Consequently, the development of a small-size carburizing and quenching furnace, which combines small-lot vacuum carburizing and gas quenching, and also a furnace that can handle one-piece flow manufacturing is being promoted and advanced.

3. 4. Machining

The production cycles for new engine and transmission components, from the advanced development to the launch phases, have been sped up tremendously to address environmental pollution, save energy, and reduce the emission of greenhouse gases. Engines have been adapted for use in hybrid vehicles, clean diesel engines were developed, smaller-sized engines are now equipped with turbochargers, and conventional gasoline engines have been improved to increase fuel efficiency. Transmissions have also advanced and customers have the choice of multi-stage automatic transmissions, automatically shifting manual transmissions, and continuously variable transmissions (CVTs). These new engine and transmission components are more complicated and diverse, and the lifetime of new models is now remarkably shorter. Emerging markets are demanding the introduction of the latest technologies from Japan, Europe, and the U.S. as these markets have expanded rapidly and the need to address environmental pollution has grown more critical. This has created a chronic shortfall in the necessary resources, including human resources in the form of well-trained workers and engineers.

In recent years, to shorten the overall development time and minimize the need for prototypes, model-based development of new engine and transmission units has become more widespread, and there are growing demands to minimize delivery times and ensure high precision work in machining processes.

Production lines are also evolving and switching over from mass production for single models using dedicated equipment to lines composed of highly versatile equipment. Equipment, processes, and jigs are all being standardized to make it easier for the line to accommodate new models, minimize delivery times, and reduce work hours. However, it is quite difficult to ensure that the production lines are able to handle various different types of models and levels of production, while still keeping the cost low. Every automaker is attempting to devise various innovative strategies to achieve these goals.

In the rough machining process for aluminum parts, such as engine blocks, cylinder heads, and transmission cases, a single-axis NC machine was adopted and the whole process was integrated. This made it possible to reduce the number of machines and also to adopt low-cost, smaller machines with a #30 spindle size. The size and weight of the jigs have been reduced by adopting hole clamps that use machined holes. This should help to make it easier to switch between different models and to lower cost.

In the case of finishing process, the most common setup is to use a dedicated process and specialized machines to ensure quality. However, a corrective device that uses measurements is employed on the high-stiffness single-axis NC machine, increasing versatility in the same way as the rough machining process, while also meeting demands for higher precision.

In the case of the engine crankshaft and steel parts in the transmission, it is difficult to integrate processes and move toward more general-purpose equipment because many different machining methods are required. However, the use of a composite lathe and single-axis NC machine has made it possible to perform lathe turning, drilling, and milling on the same equipment.

Standardizing these types of machining lines should enable deployment at plants both inside and outside Japan.

3.5. Powertrain assembly

The necessity of developing more environmentally friendly vehicle powertrains is increasing year after year. As a result, automakers have begun moving toward new types of vehicles and powertrains, such as hybrids (HVs), plug-in hybrids (PHVs), electric vehicles (EVs), and fuel cell hybrid vehicles (FCHVs). New technologies that boost the fuel efficiency of conventional gasoline engines are also making progress and are being introduced into markets both inside and outside Japan. The ability of a manufacturer to flexibly change its production mix in response to changes in market tastes and lower costs even further is now more important than ever. The realization of a production system that can make region-specific products for North America, Europe, China, and the ASEAN nations is a major issue for every automaker, and production engineering is expected to help automakers address this issue.

In this environment, production lines are being conceived and designed to produce multiple products in small lots, following concepts that can flexibly respond to sudden changes in production volume. Therefore, automakers are remodeling old lines and installing new lines based on these new concepts.

The production of multiple products in small lots is being implemented in an aim to achieve leveling (heijunka) of the work hours on the final assembly lines (i.e., to reduce the fluctuation in work content and time for each type of product as much as possible). This leveling is achieved through dividing up the assembly work according to the different engine functional parts, carrying out sub-assembly to a certain extent in advance, and changing to a modular or cell production system for final assembly. The parts to be assembled are divided up in advance according to type and then synchronized with and supplied to the final assembly lines to eliminate differences in work hours for each model. This production system can tightly control any fluctuations in work time. Other innovations include changing just the ends of the assembly tools that are used so that a single tool can be used on multiple different product models. Furthermore, robots are being used as necessary to help stabilize product quality. This use of semi-automated assembly lines is helping to advance low-cost manufacturing.

In recent years, the modularization of assembly lines has progressed even further as components are divided up according to those that change for each type and those that do not. This modularization is being promoted to reduce overall manufacturing costs. This makes it necessary to change the features of a product, not just its production technologies. Therefore, even more rigorous and thorough product development than before will also be required.

The various assembly line innovations described above are being carried out to respond to changing times and product requirements. Another pressing issue for Japanese manufacturers is ensuring a sufficient labor force to work on these lines due to the declining birthrate and aging population in Japan. In the future it will be critical for manufacturers to develop comfortable working environments that can accommodate a wider variety of workers. This may include applying ergonomics or other measures to improve the workability and visibility of the workplace so that older employees can still work without feeling physical or mental stress. It is obvious that the product development, production engineering, and production divisions will have to come together and coordinate activities like never before to achieve further progress in the field of manufacturing.

4 CAD, CAM, & CAE

In the automotive industry, the use of CAD, CAM, and CAE has played a major role in overcoming various challenges, such as shortening the development time of vehicles, improving quality, and reducing cost, especially in the production engineering field that is responsible for manufacturing.

In stamping and plastic molding processes, these technologies use product data to help predict the formability and potential for poor quality. Since these technologies can also be used to predict changes in behavior due to variations in materials and molding conditions, another possible application is to examine possible countermeasures. In processes that use general-purpose robots, such as the vehicle body painting process, these technologies are used to examine the suitability of particular process layouts and the resulting productivity for new products. In the assembly process, these technologies are used to construct virtual factories in the computer and then the assembly workability can be examined to find the optimal layout of equipment.

Obviously, these CAD, CAM, and CAE technologies are well utilized in the field of production engineering. Some quality and production problems are only discovered after trial manufacturing, but these technologies can help to improve the quality of finished products by improving the quality of drawings. This helps the engineers to discover problems more quickly and to implement countermeasures during the drawing examination stage. Since these technologies have also proven very effective at reducing the amount of reworking that needs to be done during manufacturing, this has become a main application. As today's hardware and software continue to advance and evolve, some quality and production problems that were difficult to judge with conventional outputs can now be tackled and addressed more reliably.

In stamping and plastic molding processes, efforts are underway to derive good-quality product conditions that can ensure the target quality is achieved even when mass-production conditions change. This is being done by improving the functions that automatically optimize the molding conditions. This was not possible in the past because manual optimization would have taken too much time. Advanced 3D simulation and virtual reality technologies are also being used to examine assembly workability. It is now possible to make suitable judgments about equipment locations and the layout that could not be done before. For example, 3D point group data for the existing equipment in the plant can be obtained using three-dimensional non-contact measuring devices. This data can then be combined with 3D virtual reality devices and other data about new products and equipment to create a virtual workspace that allows engineers to examine the proposed assembly line work from the same point of view as the workers.

Veteran engineers possess a wealth of knowhow, experience, and knowledge about the work procedures and evaluation criteria that must be shared with other engineers to shorten the development period for new products even further and improve quality. In addition, manufacturers are trying to find ways to achieve the optimal product quality and maintain it at a unified level so that the workmanship of the finished products in not dependent on the skills of the person in charge of working on that product. To this end, it is critical that documentation, such as measurement data plants, work procedures, and quality standards, is all tied together with the product data and carefully managed.

References

Note: the following references are in Japanese.

(1) 2014 Vehicle Production and Sales Trends in Main Markets, Japan External Trade Organiza-

tion (JETRO)
(2) Vehicle Industry Strategy 2014 (Provisional Name), Japanese Ministry of Economy, Trade and Industry
(3) Website of the Japan Automobile Manufacturers Association (JAMA)
(4) Website of the Society of Automotive Engineers of Japan (JSAE)
(5) Journal of Japan Society for Technology of Plasticity, Vol. 55, No. 643, pp. 26-28 (2014)
(6) Die and Mould Technology Journal, Vol. 30, No. 2, pp. 046-049 (2015)
(7) Press Working, Vol. 52, No. 10, pp. 40-45 (2014)