Production Technology and Production Systems

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1 Introduction

Recovering from the effects of the economic slowdown that struck simultaneously across the world in the second half of 2008, the Great East Japan Earthquake in 2011, and the flooding in Thailand, the production levels of the Japanese automotive industry returned to comparative normality in 2012. For example, production in Japan increased by 18.4% to 9.94 million vehicles (including mini-vehicles) from 2011, the first year-on-year increase for two years. However, the extreme appreciation of the yen after the global financial crisis has only accelerated the shift in production outside Japan.

Despite this trend, however, automakers are making every effort to maintain levels of manufacturing in Japan. These efforts include the development and introduction of simple and streamlined production systems capable of responding flexibly to changes in demand, as well as the development of production engineering (PE) technologies to further enhance competitiveness and the added value of vehicles.

In addition, the extension of the incentive system for environmentally friendly vehicles in Japan into 2012 increased sales of fuel-efficient vehicles, particularly hybrid and mini-vehicles. Therefore, PE technologies are likely to play an increasingly important role in the future to help further improve fuel efficiency through weight reduction and low-cost production of environmentally friendly vehicles such as hybrid, plug-in hybrid, electric, and fuel cell hybrid vehicles.

2 Vehicle PE Technologies

2. 1. Stamping

As customers increasingly prioritize safety and environmental performance, reducing vehicle weight while increasing stiffness is a key issue for simultaneously enhancing fuel efficiency and passive safety performance. Another critical recent issue is the development of lower cost stampings to help ensure competitiveness despite the recent easing in the appreciation in the yen.

One approach for reducing weight while increasing stiffness is to substitute conventional automotive materials with aluminum alloys and high-strength steels. However, aluminum production processes have several issues, including poor shape fixing performance due to the Young's modulus of aluminum, which is only roughly one-third that of steel sheets, and the adhesion of chips to the die during the removal process. These issues are being addressed through die compensation and die surface treatment technologies. Consequently, aluminum is steadily gaining acceptance as a material for body closure panels such as the hood.

High-strength steel is also being used as a replacement material. Usage of 980 MPa and stronger steel sheets is increasing, a trend which includes hot stamping processes. The issues of cold stamping with high-strength steel include the high forming force required, die wear, and poor shape fixing performance due to elastic recovery after forming. Currently, the development of die materials and surface treatment technologies to extend die lifetimes are being pushed forward by die compensation technologies that fix the desired shapes through process methods and simulations.

The adoption of hot stamping is expanding at automakers and suppliers both inside and outside Japan. This technology is capable of achieving high strengths of approximately 1,500 MPa (1.5 GPa) by forming the steel under high temperatures when the yield stress is comparatively low and then quenching the material through the surface of the die. A die correction process such as that adopted in cold stamping is not required to further improve shape fixing performance. However, after quenching, the material is hard and difficult to remove from the die. This requires the development of technology to enable localized quenching or the like. In addition, the state of contact between the sheet metal and the die during forming in hot stamping creates different material temperature histories, potentially affecting strength. As a result, it is important to confirm whether the required strength can be obtained. A wide range of studies is also examining die cooling structures and the like capable of achieving stable quenching on continuous forming lines. Consequently, simulation technologies at the study stage are likely to grow in importance.

Lower cost stampings can be achieved by reducing the number of parts through adopting high-strength steels as described above, integrating parts, reducing part thicknesses, and improving yields by optimizing part shapes and making better use of leftover material. These measures require close cooperation between the manufacturing and body structure design fields. In addition, measures to reduce die costs include integrating multiple parts in a single die, shortening processes, and efforts to achieve lighter and stiffer die structures.

2. 2. Welding

Key trends in vehicle body development include achieving greater product appeal by reducing weight to improve fuel efficiency and by enhancing passive safety performance, as well as measures to adapt to global production and environmental issues.

Weight reduction is being promoted first by replacing steel with aluminum and also by adopting material hybridization that uses combinations of multiple materials. Examples of these parts have been introduced by Japanese as well as European automakers. Technologies to join aluminum parts include mechanical methods such as self-piercing rivets (SPR) and clinching, solid-state joining such as friction stir welding (FSW), and molten joining such as laser and arc welding. In combination with adhesives, SPR, FSW, and electromagnetic welding are generally used for dissimilar material joining between aluminum and steel sheets. The purpose of the adhesive is not simply to provide strength compensation. It is also used to reduce corrosion generated by contact between dissimilar metals. Furthermore, one report described how strain caused by differences in the coefficient of linear thermal expansion of materials used for doors and other outside panels can be resolved by using a stretchable adhesive. Another report described technology for joining resins such as carbon fiber-reinforced plastic (CFRP) with steel sheets using an adhesive with bolts or laser welding.

The automotive industry inside and outside Japan is increasingly using high-strength steel sheets to reduce weight while ensuring the required strength for passive safety performance. One particular feature of this trend is the adoption of quench hardening during the forming process (i.e., hot stamping). Issues of joining hot stampings include the lower ductility and toughness of welds and areas affected by heat, which results in reduced peeling strength, delayed fractures, and the like. The thickness ratio of joined portions (i.e., the ratio of the overall thickness to the thinnest sheet in a three-layer welded structure) also tends to increase, making nugget formation by resistance welding more difficult. These issues are being addressed by the optimization of welding conditions, such as adopting two-stage power application, and the development of new joining technologies.

Production is gradually shifting outside Japan, particularly to emerging markets. Low labor costs mean that manual spot welding and arc welding are the predominant body welding processes in these markets. However, adaptive controls and other types of new welding equipment are being developed with the aim of reducing operator error and quality dispersion. These are promising technologies for improving joint quality in global production systems.

Another trend is the development of more environmentally friendly welding equipment. Reports about resistance welding have described the adoption of higher frequency currents and the application of larger currents for shorter periods of time. The introduction of green factories using robots capable of energy regeneration has also been proposed.

2. 3. Plastic molding

Requirements for plastic molding include energy-saving to reduce manufacturing CO_2 emissions, increased fuel efficiency by reducing the weight of the vehicle body, higher quality interior part textures, and measures for adapting to production outside Japan.

As an example of energy-saving measures, the electrification and hybridization of injection molders has spread to medium and large equipment. However, further energy-saving efforts will be required in the future.

Another saving energy measure is the reduction of molding pressures by adopting plastics with better flowability.

A different approach is to save energy by simplifying the supply chain, as typified by the adoption of business continuity planning (BCP) to revise the supply chain after the Great East Japan Earthquake and flooding in Thailand.

Highly functional plastics are used in control devices for motors and batteries. These materials are likely to become more prevalent as the number of hybrid and electric vehicles increases in the future.

Plastic panorama roofs and side glass have been adopted in some vehicles to reduce weight. However, the improvement of surface damage resistance is one issue for these parts. A growing number of vehicles have adopted plastic rear back doors since plastic provides a high degree-of-freedom (DOF) for shape design of plastic and can reduce the number of parts. The adoption of lower cost plastics and greater ornamentation are potential future trends.

Strong and lightweight CFRP has already started to be adopted for hoods and roofs in some vehicles. The development of thermoplastic CFRP with high productivity is also under way.

The improvement of material textures is also required for lower cost vehicles. More technologies are becoming available for processing fine grains on molds and transferring these patterns onto the surface of resins to create soft and smooth textures. Other developed technologies are capable of adding seams to inexpensive resin sheets and films before forming.

The sudden appreciation of the yen is encouraging the shift of production outside Japan. The local procurement of plastics, production equipment, dies, and the like is making progress, and global procurement trends are also gaining speed. The Japanese automotive industry must make every effort to maintain and enhance the competitiveness of manufacturing inside Japan from the standpoints of materials and equipment development, die design, and so on.

2. 4. Paint

The responsibility of the automotive paint field is to appeal to customers through color and attractive appearance. However, the painting process has a large impact on the environment and greater efforts are required to reduce emissions of volatile organic compounds (VOCs) and CO_2.

VOC emissions are being reduced by introducing waterborne primers and metallic base coats as well as by developing high solid clear coats. Low-VOC thinners for cleaning processes are also being developed and more efficient painting equipment that uses less thinner has been introduced. A combination of low-VOC thinners and increased VOC recovery rates has helped to greatly reduce VOC emissions.

Paint shops in vehicle assembly plants emit extremely high levels of CO_2. Waterborne paints require extremely strict temperature and humidity control and these processes used to consume high quantities of energy. However, major progress has been made in the painting field. The development of energy-efficient equipment and processes, a reduction in the number of processes, and smaller paint shop capacities have helped to lower CO_2 emissions. Further reductions are likely in the future as new paint and equipment technologies are developed.

From the standpoint of individual processes, zirconium oxide conversion coatings have been introduced for pretreatments and e-coating. This is reducing the number of surface conditioning steps due to the creation of stable chemical conversion coatings. At the same time, more high-throwing e-coat paints are being adopted that also ensure the optimum paint thickness for exterior panels.

Simpler painting processes are being developed and adopted that use wet-on-wet paints, which require only a single drying step after application of the top coat without drying the primer coat. This technology started to be adopted for mini-vehicles but has more recently started to spread gradually to other vehicles. Although this method may become even more widespread in the future, improved paints are required since wet-on-wet paints are more susceptible to the effects of under layers such as steel sheets and e-coats, compared with conventional three-layer, two-bake (3C2B) processes.

Painting equipment has been developed that can apply large volumes of paint to large areas very quickly. This enables the number of painting robots to be reduced. Other developments have reduced the size of paint booths by suspending robots from the walls and by using smaller robots. Painting equipment capable of coating interior panels around the door and the like has been developed, enabling greater paint line automation and smaller paint booths. Automation is likely to further increase in the future.

More dramatic color styles have emerged, further increasing the number and variety of paint layers. How to apply these layers without harming the environment is another issue for the future.

2.5. Vehicle assembly

Vehicles are manually assembled from large numbers of different parts. Consequently, competitiveness depends on improving productivity by reducing the amount of labor required to assemble a vehicle and by pursuing both quality and volume in a changing global market environment. Recently, under the concept of local production for local consumption, more production is being transferred to individual regions, particularly in emerging markets. In the shrinking Japanese market, it is important to ensure employment levels by increasing the competitiveness of existing factories, including the development of measures to respond to the declining birth rate and aging population. Automakers are competing to come up with innovations and new technologies related to both vehicle structures as well as assembly processes and equipment.

Trends in vehicle structures include commonization and standardization. The number of parts installed on the assembly line can be reduced by adopting integrated functional modules that are supplied to the line. These modules are groups of parts with multiple functions that are integrated together. Other innovations include the standardization of vehicle structures across platforms to reduce the number of part types and the leveling (heijunka) of assembly tasks.

The use of simple and versatile production equipment in assembly processes allows the line length and equipment layout to be modified flexibly in line with production fluctuations. These activities reduce the capital investment and preparation time required to change production volume or to switch models. Unlike conventional large and fully-automated equipment, this approach focuses on automation with a human element (jidoka) using simple traditional Japanese karakuri mechanisms for some processes such as part transfer, as well as technology to assist the operators using low-power and safe devices. To improve workability, assembly lines have been developed that raise or lower the transfer height of vehicle bodies in accordance with the process, partially transfer bodies transversely, and reduce walking distances by reducing the pitch between processes.

Quality is one of the wellsprings of competitiveness in the face of the changing global labor environment. In this field, the automation of part quality inspections is increasing, such as the use of image processing technology to detect defective parts. Companies in Japan are also working to actively utilize its highly experienced and skilled workforce, and to help pass on vital manufacturing skills on small volume production lines and the like.

As part of efforts to further increase productivity and respond to the declining birth rate and aging population, research is examining automated technologies that allow robots and human operators to work together safely. Controls are being developed that enable soft impacts even if a robot collides with a worker. This research also includes the development of wearable assistance technologies.

3 Powertrain PE Technologies

3.1. Casting

Emissions and fuel economy regulations are becoming more stringent from the standpoint of preserving the global environment. Consequently, the automotive industry is working on a range of environmentally friendly measures. The demand for hybrids and other environmentally friendly vehicles is increasing as fuel prices rise and preferential tax systems are introduced that favor fuel-efficient cars. Other recent trends include the introduction of downsized turbocharged engines and greater use of aluminum castings in the body structure as well as the suspension. It is important to create appealing and inexpensive products to respond quickly to changes in customer needs and market trends. Therefore, the development of highly functional powertrains is necessary. Casting is regarded as an increasingly promising technology to create complex shapes and to reduce thickness and weight.

The use of 3D data is expanding to reduce lead-times and to improve casting accuracy. To speed up development, the design evaluation period can be shortened by producing parts using sand mold casting using 3D modeling technology without wooden models. The results of CAE analysis of metal flows and solidification can be incorporated into product shapes and reflected in mold design. As a result, quality can be assessed before the manufacture of metal dies. In the die manufacturing field, the linking and synchronization of 3D product and die design data is helping to shorten die delivery times. In this way, uniform 3D data can be used from the product design to the evaluation and die manufacturing stages, helping to shorten lead-times and to improve casting quality.

Environmentally friendly measures such as energy saving, eliminating the use of hydraulic oil, and the like are being adopted in production equipment. Conventional die casting machines capable of efficiently producing aluminum parts generally used hydraulic pressure as a drive mechanism. Although die closing processes have already been converted to electrical drive, new fully electrical die casting machines have also been introduced that use no hydraulic mechanisms even in the injection process. These machines should help to save energy and improve product quality through highly accurate injection control.

In the casting field, every effort is being made to develop parts with more complex shapes, to reduce part thicknesses and weight, and to respond quickly to the demand for new functional parts used in next-generation electric and fuel-cell vehicles. These goals are being achieved by activities to achieve faster die development using 3D modeling technology, shorter lead-times from the design to manufacturing phase, the accumulation of technical know-how, and the building of competitive production lines.

3. 2. Forging

In recent years, reflecting efforts to preserve the global environment and to utilize resources more effectively, demand is increasing in developed countries for hybrid, plug-in hybrid, and more fuel-efficient conventional vehicles. However, in the BRICs and other emerging countries, demand for compact and inexpensive vehicles is increasing. Consequently, automakers have to develop a wide range of products to meet the various needs of customers.

Demand for forgings is also gradually changing. For drivetrain parts such as hybrid systems and continuously variable transmissions (CVTs) adopted to improve fuel efficiency, and engine parts such as turbochargers and variable valve mechanisms, designs are still relatively new. Therefore, it is important to create drawings that achieve both functionality and productivity, and to improve production processes. For conventional parts, development activities are focusing on the net shaping of gears to shorten cutting processes, the hollowing of shaft parts to reduce weight, and the improvement of yields and accuracy of crankshafts and other hot forgings to reduce manufacturing CO_2 emissions and costs. In contrast, many drive parts such as hybrid vehicle motor cores and CVT belts still use steel materials. The accuracy of these parts has a direct impact on the functionality and performance of the product. Although the manufacturing accuracy tolerances of these parts are measured in microns, high-speed production of several hundred per minute is required since these parts are used in large numbers on each vehicle. Consequently, die manufacturing technology and accuracy control technology at the part manufacturing phases are making dramatic progress. Measurement technology using image processing, lasers, and the like is contributing to this progress.

The globalization and localization of production is continuing to expand. Since the production volume at each local plant is lower than at a large centralized plant, automakers are looking to develop a small-volume local production model to replace the high-volume centralized production model that suits the conventional advantages of forging. One approach to achieve this aim has been to simplify and downsize production equipment. To accelerate this trend, the automotive industry is actively adopting sequential forming methods and servo presses capable of forming parts at lower loads.

One concern is the hollowing out of the Japanese automotive industry as local production expands and demand in Japan recedes. In 2012, the results of a government-sponsored research project were published that described controlled forging technology for connecting rods, which aims to achieve groundbreaking levels of weight reduction. This method strengthens the critical column portion while ensuring the same levels of strength and machinability as conventional parts for other portions. The Japanese automotive industry cannot compete on cost alone, and this is a typical example of the highly functional products that can be manufactured in Japan. Strengthening PE technology capabilities to enable the mass production of these products may well be the driving force behind the future sustainable growth of the automotive industry in Japan.

3. 3. Heat treatment

Heat treatment is capable of achieving various targeted functions by applying appropriate amounts of heat and cooling to a part. It is a critical and indispensible process in manufacturing. In the heat treatment field, technologies are being developed to help preserve the global environment by reducing CO_2 emissions through improved productivity and energy saving. Simultaneously, these technologies are aiming to enhance strength and accuracy for more complex product shapes by reducing part weights and integrating functions. At the same time, promising production systems are also being introduced that are robust and flexible in the face of production fluctuations.

Gears and other drivetrain parts are generally manufactured by gas carburizing and quenching. However, the adoption of cell-type vacuum carburizing furnaces is spreading to help achieve the goals described above. This method involves high-temperature carburizing that increases strength and shortens the processing time without generating the internal oxidation that occurs with gas carburizing. It also uses high-pressure nitrogen gas cooling in place of quenching oil. Steel materials for gear teeth suitable for these technologies are also being developed.

Conventional carburizing and quenching assumes high-volume production to reduce processing costs. After the global financial crisis, the automotive industry has moved to review production scales. Consequently, carburizing and quenching devices have been proposed that can be incorporated into small-lot machining lines.

Induction hardening is widely used for large chassis parts such as crankshafts and constant velocity joints since it obtains high compressive residual stress and hardness, and is simple to incorporate into machining lines. In recent years, studies have examined methods such as low-distortion quenching to eliminate post-treatment, and contour hardening for gears using dual-frequency heating to obtain high strength equivalent to carburizing and quenching. The aim of these methods is to further increase added value. It is becoming increasingly important to produce multiple models on the same production line to respond flexibly to fluctuations in demand. Induction hardening equipment that can be switched over in a short period of time has been developed by minimizing the number of dedicated parts that are required for each model.

Parts used under high surface pressures or under low-lubrication conditions, such as fuel injection pumps, piston pins, and so on, are increasingly using dry coatings such as diamond like carbon (DLC) to ensure seizure resistance and sliding performance. Current efforts are aiming to reduce processing costs by developing large inline machines and to improve functionality by developing coatings with multiple layers.

Other research reports have described the reduction of nitride gas usage by adopting nitriding potential control and the development of highly functional technology. Other reports have been published related to surface modification technology using fine particle bombardment, as well as plasma lasers. Heat treatment simulation technology continues to make rapid progress as software and hardware functionality improve. The analytical accuracy of deformation and stress as well as temperature and microstructures has improved dramatically and should be adopted in product design and heat treatment condition studies in the future.

3.4. Machining

The supply of automotive parts and tooling was thrown into disarray by the Great East Japan Earthquake and the damage caused by the flooding in Thailand in 2011. In 2012, the production of environmentally friendly vehicles increased and Japan entered a manufacturing crisis caused by the extreme appreciation of the yen. Consequently, there is an intensifying need for small-scale machining lines capable of adapting flexibly to changes in production. Previously, machining lines were geared for mass production using dedicated equipment. Now, technologies to reduce costs and increase accuracy are being developed and introduced to integrate processes on versatile equipment capable of small-volume production.

In the case of rough machining of large parts such as the engine block, there has already been a move toward the integration of processes onto one-spindle machines with a tool replacement mechanism and rotating table. Other trends include the adoption of lower cost and smaller devices (i.e., devices with a main spindle tip size of #30 or less) that use low resistance machining, the reduction in the number of processes by eliminating tapping, and the adoption of compact and easy to change jigs that clamp using the positioning holes of the product.

Conventional finishing processes generally used dedicated equipment and methods with strict accuracy requirements. Tool clamping mechanisms with high stiffness and fluctuation accuracy are now being used in boring and surface machining. In combination with highly accurate correction technology using position measurement, more processes are being integrated on one-spindle machines.

The machining of shafts such as in the transmission includes many steps before completion, including drilling, turning, as well as gear tooth cutting and grinding. This is a bottleneck preventing further integration. Consequently, combined machining equipment has begun to be used that functions as a lathe but that also has a turret spindle head capable of being attached to rotating tools such as end millers and hob cutters. Research is also under way to incorporate turning and ultra-fine finishing processes after quenching.

Since end milling used in these versatile methods is expensive, development is under way to extend lifetimes and reduce costs. For example, AlCrN coatings with excellent high-temperature strength are being adopted for steel, and hard DLC coatings with excellent adhesion resistance are being adopted for aluminum. The collection and recycling of the carbide base material has been extended from used tools to grinding powder in reaction to cost increases of the main rare earth elements such as tungsten and cobalt.

For both blocks and spindles, the importance of coordination among product design, raw materials, and machining is likely to increase. This will involve measures such as revising product structures from the standpoints of shortening processes and the ease of manufacturing. At the same time, new materials are starting to be adopted for automotive parts to reduce weight and to improve fuel efficiency. Many of these materials are generally difficult to machine, which will further increase the need for new machining methods and tools. Examples include reducing the portions requiring machining by net shaping, the machining of CFRP body parts and heat-resistant cast steel used for turbocharger housings, the development of peeling processes for the enamel coating layers of hybrid motor copper wiring, and so on.

3.5. Powertrain assembly

As customer demand for environmentally friendly vehicles increases, powertrain components are becoming more hybridized, smaller, and lighter. Measures to meet market needs as quickly as possible while minimizing costs are critically important both inside and outside Japan. In other words, rapid production-based measures to respond to sudden increases and decreases in order volumes in each region and the flexibility to fill a wide range of orders for gasoline, diesel, and hybrid powertrains are an absolute necessity. The automotive industry is relying on PE technologies to manufacture products that meet the characteristics of local markets while fulfilling the requirements for production volume, variety, and cost reduction. Production line formats are being switched from the conventional approach of producing large volumes of a low number of units at the same plant to small-volume production of multiple units in regional markets.

To facilitate the production of multiple unit types, developing sub-assemblies supplied in advance to the assembly process as functional modules is one way of reducing the number of unit types in the main assembly process. Creating grouped sets of parts for each type in advance also aids part selection and reduces waste in main assembly.

Sudden fluctuations in order volumes require rapid reaction to increase and decrease the number of assembly processes. Therefore, innovations are being introduced to allow flexible and fast response to process changes by reducing the size and weight of assembly tools and the jigs used to position products, and so on.

The switchover to small-volume production of multiple units also requires actions from a product standpoint as well as the development of assembly tools and jigs and automated equipment.

From a product standpoint, product design is changing to accommodate the production of multiple unit types by unifying the shapes of basic portions in product structures. This reduces the number of various parts required, from bolts to larger parts. In addition, eliminating the need to categorize tools and jigs used on assembly lines part-by-part simplifies assembly work and part supply. This facilitates the response of the production side to changes in unit types and volume.

Technological approaches for cost reduction include the development of equipment to integrate processes and make assembly lines more compact, as well as the development of basic technologies for tools and jigs in line with regional characteristics. Fast and global adoption of these core technologies will only grow in importance in the future.

4 CAD/CAM/CAE

The practical application of CAD, CAM, and CAE is expanding at every company in the automotive industry as core digital engineering technologies to revolutionize development processes. The various PE fields will play major roles in shortening development lead-times, improving quality, and reducing costs.

In the past twenty years, CAD has evolved to express shapes through wire frames, surfaces, solids, and parametric modeling. In combination with advances in hardware technology, highly realistic shapes can be expressed even on PC terminals. In addition to CAD for detailed design work that can express the free-form surfaces required by designers, various tools that can also utilize attributes of product and process information and that meet the needs for each process are advancing rapidly. Examples include simplified CAD used for designing equipment in the production engineering and manufacturing fields, and viewer technologies that can express overall vehicle views and part configurations on hand-held tablets.

Joint CAD/CAM developments are also taking place. As an example of a function to support improvements in design technologies with the aim of quantifying engineering skills, knowledge systems are being developed that collect judgment references and reference information in design procedures, as well as the design and manufacturing know-how of veteran staff members. Such systems enable anyone to find optimal solutions for cost, performance, functions, and the like, and also help to maintain uniform levels of quality.

Pre-verifications using CAE aim to reduce costs and to shorten the development period. Various test cases can be set under conditions that are not feasible with actual vehicle tests. This allows quality assurance by analysis from the initial design phase. In addition to conventional structural analysis of strength, stiffness, deflection, and so on at the design phase, these methods are also being adopted for ensuring quality during mass production by analyzing manufacturing processes. In addition, tolerance analysis software is now being adopted to achieve the required quality within the capabilities of the process. This software identifies the dimensional feasibility of component parts of a completed vehicle, factoring in dimensional dispersion and the factors affecting the dispersion.

Finally, as CAD and other digital engineering methods advance, there is an increasing need for 3D verification to confirm that product shapes are consistent with CAD models. In line with recent advances in measurement technologies and the digitalization of measurement data, the application of 3D shape measurement technologies in each process from design to manufacturing is contributing to high-quality vehicle manufacturing.

References

(1) Japan Automotive Manufacturers Association Website
(2) Chikaoka: Honda Achieved the Practical Use of steel/aluminum hybrid door, The Solution Magazine for Design and Manufacturing, P62−67 (April 2013)
(3) Furusako, et al.: Current Problems and the Answer Techniques in Welding Technique of Auto Bodies-First Part, Nippon Steel Technical Report, No. 393, p. 69−75 (2012)
(4) Takemoto, Proposal for Turning Welding Factorirs into Green Factories, Welding Technology, July, Vol. 60, p. 45−48 (2012)
(5) The Heat Treatment, Vol. 52, No. 3 (2012)
(6) The Heat Treatment, Vol. 52, No. 4 (2012)
(7) Websites of respective car manufactures
(8) Websites of respective CAD companies.