Frontier & Platform Research for System Development and Monozukuri

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SYSTEM CONSIDERATIONS IN MONOZUKURI MANUFACTURING

THE modern world faces many very difficult challenges, including global warming, resource and energy depletion, and rapid socioeconomic change. At the same time, while rapid progress is being made on establishing the foundations of a prosperous society, there are also calls from around the world for highly reliable social infrastructure that provides safety and security while being conscious of the global environment, including the changes needed to bring about a low-carbon society. Future manufacturing will need to undertake design, development, and production based on a global overview of the overall system for product creation and supply.

For the platform technologies that support manufacturing, this will require moving beyond the focus on specific technologies adopted in the past toward a system-based approach, with technology able to provide low cost, high performance, and high reliability throughout all phases of the manufacturing process.

The following two factors are considered to be important for developing a wide range of systems and other products globally: (1) Integration of a diverse range of multidisciplinary technologies to complement the existing technologies, which include simulation, testing and measurement, and production. These multidisciplinary technologies include advanced information technology (IT), computational engineering, data analysis techniques, systems, and service technologies. (2) The development of techniques for understanding, predicting, and controlling complex phenomena that occur in systems through the integration of models of real-world phenomena that span different scales.

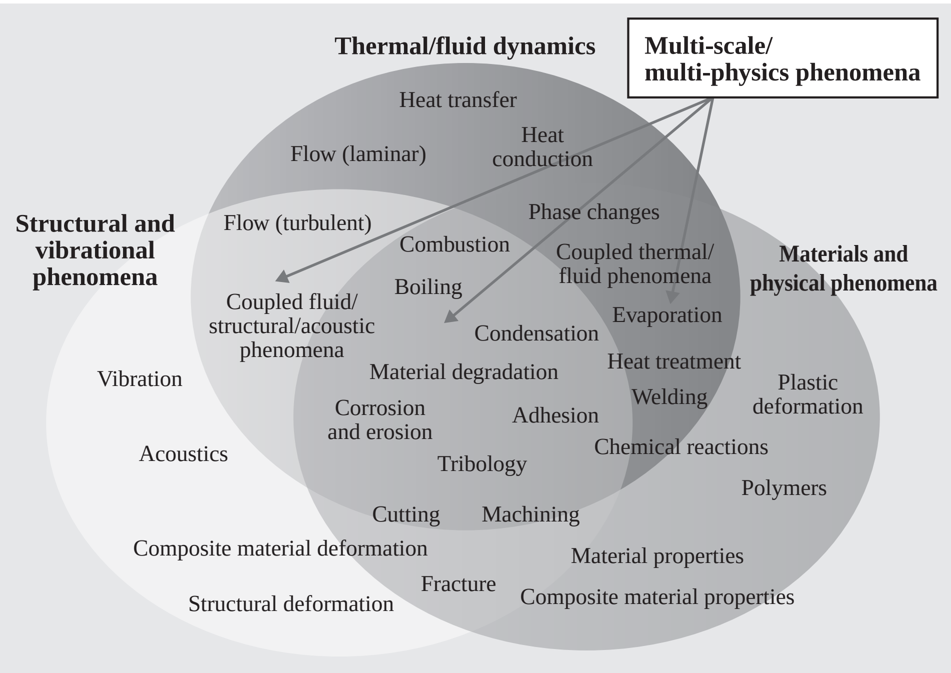

Fig. 1—Complex Multidisciplinary Coupling Phenomena in Mechanics and Materials.
There will be a need in the future to elucidate multi-scale and multi-physics phenomena that relate to a number of different fields. Examples include surface phenomena and coupled phenomena such as material degradation, corrosion, evaporation, and tribology.

ROLE OF PLATFORM TECHNOLOGIES

"Platform technologies" are common technologies that support a range of different manufacturing platforms. They cover a variety of fields, including simulation, measurement, and production technology. In particular, it will be essential in the future to deal with things like environmental problems and the greater diversity of requirements resulting from the globalization of markets.

Monozukuri in Social, Industrial, and Information Sectors

To accelerate the globalization of its products for the social, industrial, and information sectors, and improvements to their environmental performance, Hitachi recognizes a number of common core technologies as being platform technologies. These include analysis-led design techniques that use the latest simulation and measurement technologies, technologies for reducing the load on the environment, and production technologies that support globalization and improve productivity.

The fields in which these are applied include electric power, water and sewage supply and treatment, railways, automotive equipment, industrial and urban development systems, healthcare, information and telecommunication systems, and the advanced materials technologies, key devices, and other products that support these different sectors. Organically fusing the systems and technologies that Hitachi has built up in these diverse sectors will create an infrastructure that can act as the platform for a sustainable society able to reduce the load on the global environment while also providing a comfortable way of life and economic growth.

Platform Technologies from a Global Perspective

Because the product creation and supply system must operate in complex and diverse cultural and natural environments, managing a worldwide business requires a different approach to design than in the past. This involves more than just taking account of the complexity of the environment in which each product is used; it is also essential to achieve reliable cost and quality while also speeding up design, development, and production. A system-based approach to manufacturing is also needed. Together with extreme designs able to deliver high performance and low cost, this also calls for advanced platform technologies based on an understanding of complex phenomena.

Taking the mechanics and materials sector as an example, whereas in the past this sector tended to use models that represented phenomena in terms of a single field of study, the increasingly stringent demands being placed on product performance make it necessary to understand and control, as thoroughly as possible, multi-scale/multi-physics phenomena that inherently combine a number of different disciplines, such as tribology[a], material degradation, and coupled phenomena[b] (see Fig. 1).

The monozukuri approach to manufacturing also includes the following considerations.

(1) Succeed in staying ahead of rivals by improving, as far as possible, factors such as performance, quality, and cost for products that are based on existing concepts. For example, one approach is to develop next-generation products able to be used in harsher environments by improving materials, with any gains in performance also being important. Also, develop stand-out technology to keep ahead of similar products.

(2) Take a variety of approaches to resolving problems or satisfying needs, and develop products, systems, and services that use new technologies or concepts that implement these solutions.

However, using approach (1) on its own makes it difficult to differentiate products as technology matures. This means that combining both these approaches will be important in future research and development.

Given this background, in addition to manufacturing platforms based primarily on conventional production technology, what will also be required will be to construct a diverse infrastructure of platform technologies that are capable of working together. Examples of these include system platforms that incorporate control technology and involve performing design and operational simulation from a systems perspective, and information platforms that utilize

(a) Tribology
The Japanese Society of Tribologists (JAST) defines tribology as the science and technology of all phenomena that occur at the interface between two surfaces that interact through relative motion. This includes lubrication, friction, wear, seizure, and bearing design. The word derives from the Greek "tribos," meaning "to rub," and "ology," meaning "to study."

(b) Coupled phenomena
Phenomena or behaviors that involve the interaction of two or more features, such as structure, heat, flow, electric fields, magnetic fields, or acoustics, and therefore cannot be predicted based on consideration of a single feature on its own. The analysis of such phenomena is called coupled analysis.

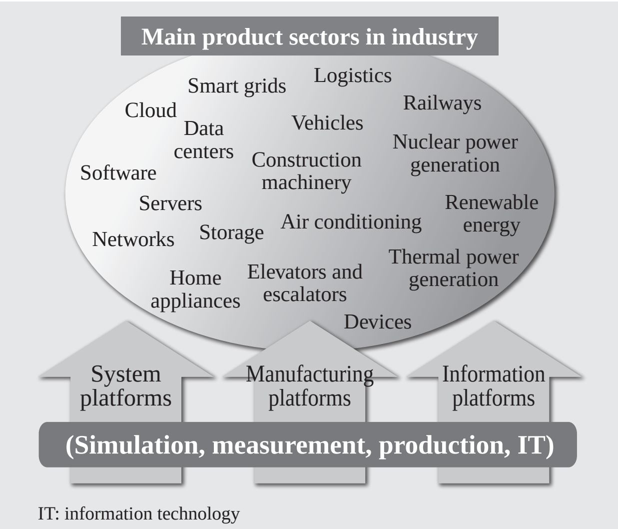

Fig. 2—Platform Technologies that Support Systems for Product Creation and Supply.
A wide range of platform technologies, including manufacturing platforms, system platforms, and information platforms, are used by industry to support the production of numerous different categories of product.

information science to deliver large-scale data processing and other solutions (see Fig. 2).

For example, system platforms include platform technologies such as simulators for the smart grids that will be needed in the future, operational simulations for railways and other applications, and model-based technologies that predict system functions. Examples of information platforms include large-scale data processing at data centers, encryption techniques for security, recognition techniques based on information science, and network, cloud and storage technologies. These will be essential platform technologies for supplying global systems and solutions (see Fig. 3).

Also needed will be the integration of different platforms, with technologies such as simulation, measurement, production, and IT acting as common cross-platform technologies.

USE OF PLATFORM TECHNOLOGIES IN SYSTEM-BASED MANUFACTURING

As described earlier, conducting manufacturing operations on a worldwide scale can be thought of as requiring complex perspectives and considerations, and this in turn requires the integration of multidisciplinary platform technologies that span different fields. Nevertheless, advanced and in-depth specialization in each field remains a prerequisite for achieving these diverse forms of integration.

The following sections give a broad overview of future developments in the simulation, measurement, and production technologies for manufacturing platforms in particular.

Simulation (Computational Engineering and Computational Science) Techniques

Improvements in computer performance have made it possible to conduct large and complex simulations. In the field of thermal fluid and structural analysis, these include coupled analyses of fluids, structures, and noise; coupled analyses of electromagnetic fields and circuits; and whole-product simulations(1). Meanwhile, material simulations are inching closer to an understanding of complex systems, including simulations of microstructural changes in metals and those that use physical properties data to combine macro-scale phenomena with micro-scale analysis of atoms and molecules(1). However, the current state of technology is still unable to make accurate predictions

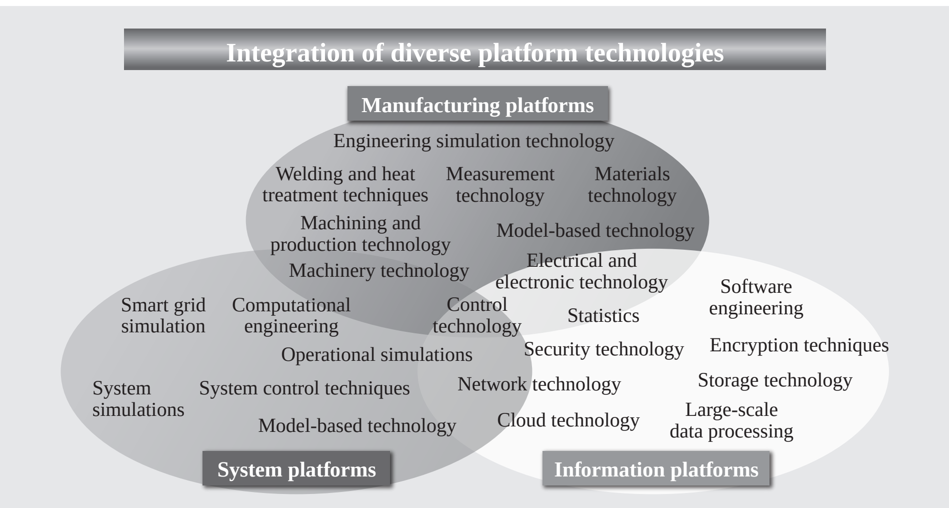

Fig. 3—Diverse Platform Technologies and their Integration.
The integration of platform technologies such as those for manufacturing, systems, and information will be vital for supplying global solutions.

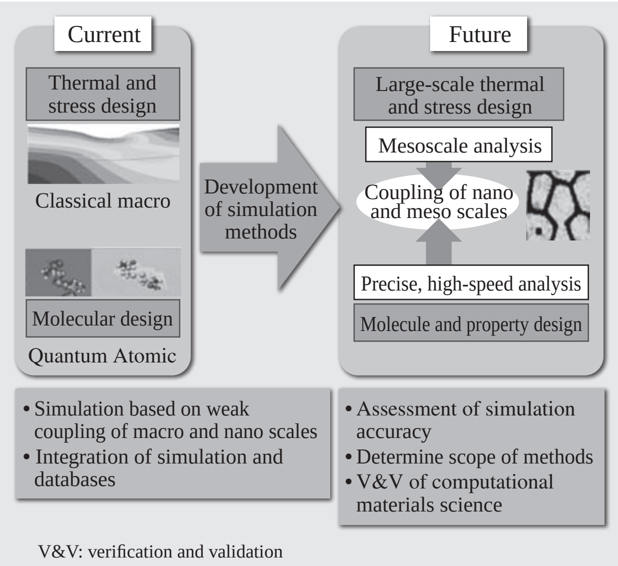

Fig. 4—Need for Mesoscale Material Simulations.
Modern material design and development requires the development of mesoscale models that take account of nano-scale properties, and their use for analysis.

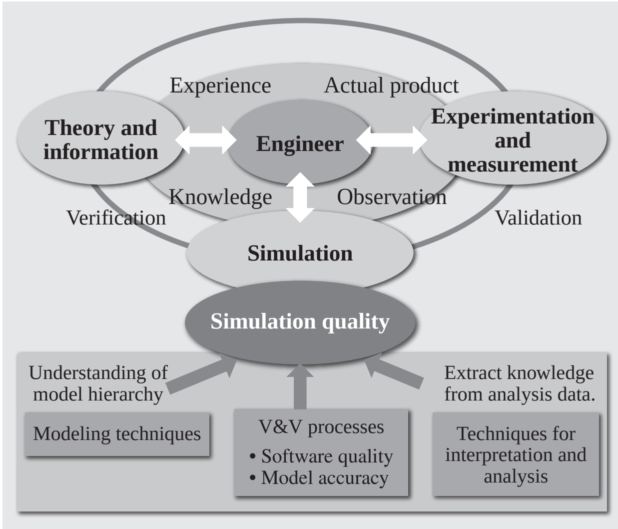

Fig. 5—Concept of Simulation Quality.
Advanced techniques such as modeling, V&V processes, and the interpretation of analysis results are required to improve simulation quality.

of complex phenomena. Examples include unsteady phenomena in fluid machinery, combustion involving complex reactions, and the machining, welding, lubrication, corrosion, and other processes associated with materials. Also of importance for material simulations are mesoscale[c] analysis techniques for predicting the influence that micro-scale material properties have on macro-scale product performance (see Fig. 4).

To increase the number of product functions and satisfy diverse needs, it is also necessary to obtain multipurpose and appropriate solutions. A number of optimization techniques are being developed for this purpose[1]. As relying solely on simulations based on physics and chemistry to achieve this, as in the past, will be difficult, it will be important in the future to incorporate approaches based on optimization, computational engineering, and information science.

It is anticipated that the elucidation and control of phenomena that are diverse and difficult to predict will occur in a global environment. What will be even more important in the future will be establishing the concepts and processes of V&V[d] for interpreting the suitability and guaranteeing the accuracy of the techniques used to simulate the complex phenomena involved[2]. To achieve this, it will be necessary to establish the processes of verification (for determining whether the computational models used for the phenomena being dealt with are appropriate in theoretical and mathematical terms) and validation (the use of advanced measurement techniques, comparison with actual phenomena, and other means to assess the suitability of analytical models), and to integrate them with other platform technologies, such as those for measurement and production (see Fig. 5).

Also, as it is impossible to predict the behavior of practical systems using simulation alone, it will also be necessary to develop modeling methods that successfully integrate with measurement technology, large-scale data processing, and other approaches. In the field of weather forecasting, for example, new integration techniques such as data assimilation[3] are being developed, and their use in industry is also anticipated.

The key requirements for the future use of simulation are as follows.

(1) Precise modeling of large and complex phenomena
(2) Interpretation of large data sets containing analysis results

(c) Mesoscale
The prefix "meso" means "intermediate" and the term mesoscale refers to spatial scales midway between the nano and millimeter range. This range includes structures that play an important role in determining material properties. As the mesoscale is midway between the realms of classical and quantum mechanics, analysis of phenomena at this scale requires the design of models that take account of both types of behavior.

(d) V&V
Abbreviation of "verification and validation." A method for ensuring the quality of systems, services, and other products. In product development, for example, V&V may refer to an assessment (involving both verification and validation) of whether the development, design, production, and other processes are appropriate in order to determine whether the resulting product will be fit for purpose.

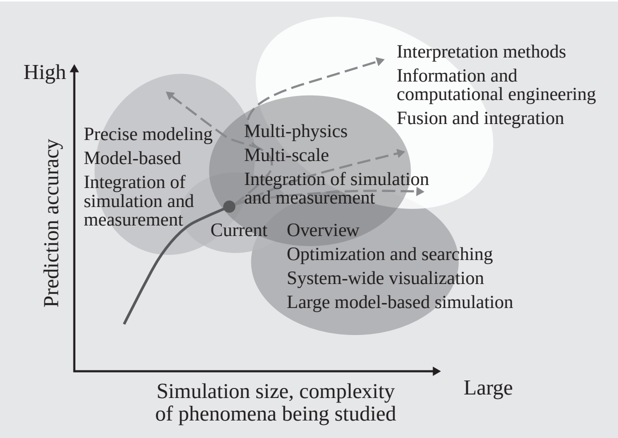

Fig. 6—Diverse Approaches to Computational Engineering.
A diverse range of optimum approaches to simulation (computational engineering) exist depending on factors such as prediction accuracy and the complexity of the phenomena being studied.

(3) Precise modeling of phenomena that have not been well understood in the past
(4) Taking account of scatter, variation, and other random factors that influence analysis

As the product creation and supply system becomes more complex, the quantity of data produced by simulations is growing. In an increasing number of cases, this is making the interpretation of analysis results more difficult. In situations such as these, even when simulation is being used, it is important to select analysis methods that are appropriate to the complexity of the phenomena being studied, as well as in terms of accuracy and other factors (see Fig. 6).

Measurement Technologies

Measurement lies at the heart of science and technology, which advances through a repeated process of theoretical prediction and experimental verification. As the natural world still contains many phenomena that are difficult to measure or visualize, even more advanced measurement technologies are needed. Meanwhile, of increasing importance for the products that play a fundamental role in society, such as vehicles and industrial plants, are initiatives that provide ways for Japanese companies to differentiate themselves against a background in which costs are falling globally, such as using measurement to underpin reliability and the modeling of complex phenomena.

The current issues for measurement technology can be broadly divided into the following three. As an example, Fig. 7 shows the requirements for measurement and evaluation in electronics manufacturing.

(1) Soft materials and water-containing materials play a large role in the field of environmental and biological materials. A common challenge for these is to perform measurements in a way that produces an efficient signal, but with low damage and without disturbing the state of the specimen. In the case of graphene, polymers, and many biological specimens,

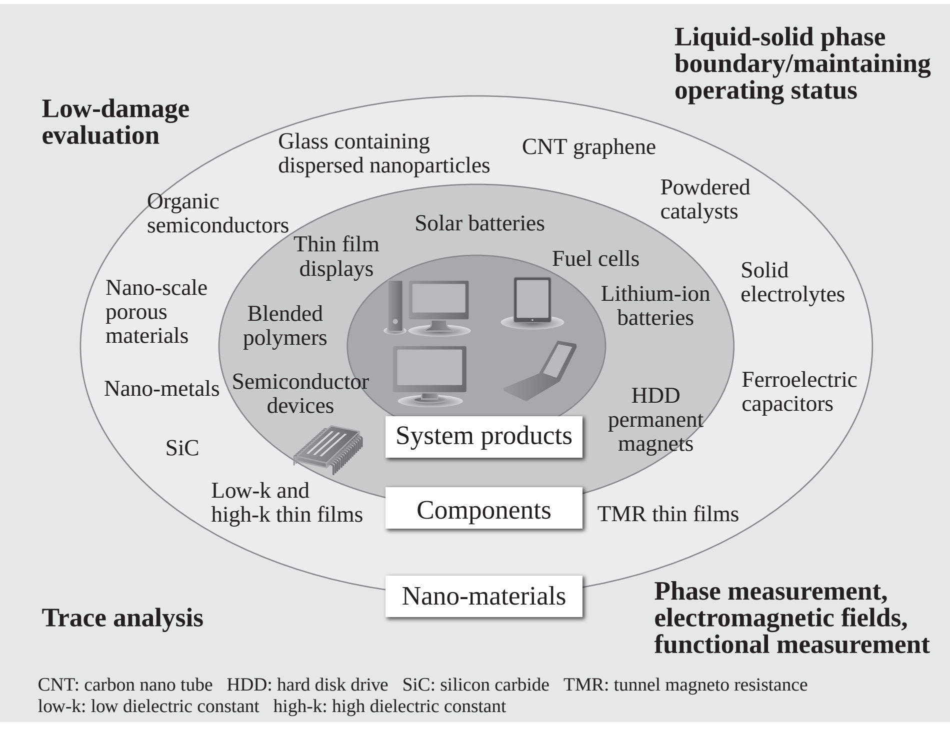

Fig. 7—Diverse Requirements for Measurement and Evaluation in Manufacturing (Electronics Industry Example).
The electronics industry has diverse and wide-ranging requirements extending from system products to individual components and nano-materials.

materials that are damaged even by exposure to light are becoming increasingly common. When testing the electrode materials used in lithium-ion batteries, it is necessary to study the liquid-solid phase boundary at the nanometer level as they undergo changes if removed from the electrolyte. Similarly, measurements of functional particles such as catalysts need to be performed at the gas phase boundary, which is where they are used.

(2) A wide range of medium to large products such as industrial plants, vehicles, construction machinery, electric motors, and materials require non-destructive, non-contact, and non-contaminating measurements, as well as portable, low-cost measurements that can be used in the field. The technical challenges to visualizing three-dimensional distributions and internal structures with high spatial resolution remain numerous. Similarly, on-site measurements are required for situations such as combustion phenomena in boilers or the flow rates and pressures in the complex rotating flow fields in fluid machinery.

(3) High-speed inspection techniques for applications such as detecting contaminants or agricultural chemical residues in foods are another pressing issue. This will be an important area of activity in the future, and will need to cope with different national regulations and other laws as well as challenging throughput and cost requirements. Measurement technology will also need to support material development to help with the move away from using rare earth elements.

The following lists the measurement platform technologies that will need to be considered in the future to respond to the above challenges.

(1) Techniques for controlling and detecting phase are important when electron beams are used for measurement. Platform technologies that will be important include electron optics that allow atomic-scale observations to be made using low-energy electron beams, detectors and analyzers able to discriminate between different signals, and high-intensity pulsed electron guns. These will allow for innovation in material and device development using soft materials based on light elements, specimens of which produce weak signals.

(2) Probe microscopy works by scanning a fine probe over the sample. Because it does not require a vacuum, probe microscopy can be used for highly efficient nano-spectroscopy[e] using near-field light[f], and to analyze the properties of liquid-solid phase boundaries. This represents a breakthrough in the structural analysis of water-containing specimens, proteins, and genes.

(3) Measurements performed at large facilities, such as those involving synchrotron radiation or neutron beams, can be used for non-destructive structural analysis at the atomic level. Successful results have been reported for a wide range of applications. Examples include evaluating the structure of electrodes in actual lithium-ion batteries without having to open up the battery package, evaluating the internal stresses in products, and evaluating the magnetic domains in a permanent magnet using beams of polarized light. Also measurements that use a pulsed beam to improve time resolution can be used to study transient phenomena such as chemical reactions and changes in molecular structure. It is anticipated that this technique will open up new possibilities in fields such as molecular material design and drug development.

(4) Medium-sized and large products require non-destructive testing techniques to ensure their reliability. Penetrant inspection and length measurement techniques have been commercialized using X-rays, ultrasonic wave, eddy current, laser beams, and other methods, and active progress is being made in areas such as the three-dimensional representation of information and making measuring instruments smaller and more portable.

Future applications are anticipated in areas such as resource mapping. In the case of thermal fluid and acoustic field measurement, technologies are needed that can integrate with simulations and measure entire specimens.

Production Technology

With the globalization of business, overseas production (particularly in Asia) is becoming essential for achieving cost-competitiveness.

Japanese manufacturing has led the world through globally superior technology, including production systems and integral manufacturing in the production workplace. However, these will not necessarily

(e) Nano-spectroscopy
A technique for analyzing structures by measuring how a specimen responds to light (including absorption, reflection, refraction, and dispersion) on the nano-scale. Traditionally, the spatial resolution of spectroscopy has been limited to approximately the wavelength of the light being used (several hundred nanometers in the case of visible light). Using near-field light, however, it is possible to achieve nano-scale spatial resolutions that exceed the diffraction limit of the light.

(f) Near-field light
A special type of light that is produced when light is applied to physical structures such as very narrow apertures or edges that are smaller than the light's wavelength. This near-field light does not propagate beyond the immediate vicinity of the surface of the structure. Because it has a wavelength shorter than visible light and is able to exceed the diffraction limit, it can be used to dramatically enhance the spatial resolution of optical microscopes.

function effectively if transplanted directly into overseas production sites, and it has become clear from actual experience of overseas production that the issues facing the manufacturing workplace cover a wide range. All of these issues, which include workers, procurement, supply chain, local infrastructure, local regulatory and commercial practices, and intellectual property, take considerable time and effort to resolve. Furthermore, remaining cost-competitive takes more than just focusing efforts on the manufacturing workplace, and the need for innovation in upstream processes such as product planning and design has already been discussed.

Accordingly, thinking about production technology for global manufacturing must go beyond just the technology at the manufacturing workplace and encompass a major conceptual change from a global perspective. The following seven topics represent the key considerations for achieving this.

(1) Trouble-free construction of factories, plants, and other facilities
(2) Establishing a supply chain, including procurement
(3) Optimization of factory production lines
(4) Workers
(5) Procurement (how to respond to variations in quality, delivery times, and other disruptions)
(6) Optimization of production across multiple sites spread over a wide area
(7) Optimization of maintenance and support

While these include some elements that are not part of conventional production technology, Hitachi believes that they are all appropriate subjects for research and development and represent production technologies for responding to the challenges of global manufacturing.

Among these, use of simulation is a particularly important platform technology (see Fig. 8).

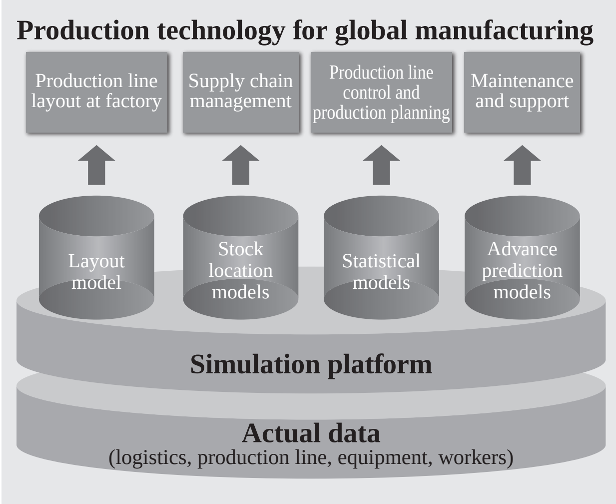

Fig. 8—Use of Simulation to Support Global Production Technology.
Use of simulation techniques that combine with statistical models, stock location models, and similar will be essential in the future.

The following sections describe the production technologies of global manufacturing for each of the above seven topics, considered primarily from this perspective.

(1) Construction of factories and plants needs to be thought of as comprising two stages: design and execution. Important technologies for the design stage include multi-dimensional computer-aided design (CAD) and simulation, which are used for tasks such as site selection, design of the plant layout, and logistics design. The execution stage requires techniques for managing schedules, cost, and resources across the entire construction project, taking account of a large number of considerations and constraints, and techniques for overall planning of material procurement, transportation, and site delivery.

(2) The importance to manufacturing of the global supply chain (including procurement), and its fragility, were exposed by the earthquake and flooding disasters of 2011. Use of simulation is essential to study how to achieve a smooth supply chain based on an accurate appreciation of the actual conditions in each country and region obtained in advance.

(3) While manufacturing process design based on the structure of the product being produced and the planned production volume has a fundamental role in determining production line layout, establishing production equipment layouts, worker deployments, space designs, and internal factory logistics that achieve high efficiency for a low investment requires digital factory technology (combining simulation and animation) that can determine in advance whether designs are optimal and achievable.

(4) Techniques such as automatically generating easily understood work instructions or taking steps at the design stage to simplify assembly are an effective way of dealing with workers whose skills are lacking. The "assembly reliability evaluation method"(4) is an effective technique for use with designs that simplify assembly. This evaluation method quantifies the ease of assembly of proposed designs. It considers the ease of assembly of each component, one at a time, and estimates the rate of assembly defects by quantitatively assessing the working capabilities of each production site.

(5) While encouraging improvements by suppliers is a necessary part of procurement, it is also important from a production perspective to adopt robust machining and assembly techniques that assume a degree of variability in supplied parts. Variability in part delivery times is also to be expected and this requires realtime production management techniques.
(6) The important factors for optimizing production across multiple sites spread over a wide area are to adopt realtime practices and improve the accuracy of production line control and production planning, and to establish a supply chain that operates in synchronization with production. Detailed simulation is key to both of these objectives and the use of more advanced techniques is essential.
(7) Reductions in the cost of reliable maintenance and support can be achieved through an accurate appreciation of maintenance intervals acquired by taking note of warning signs.

Extending these production technology concepts makes a systems-based approach more important, and the development of more advanced simulation techniques can be seen as a major technical challenge.

While this article has so far considered production technology from a systems perspective, improvements in hardware technology are also important. In particular, the phenomena associated with platform technologies that support highly reliable systems such as machining, welding, lubrication, and surface treatment are complex, and this is a field in which modeling is not yet well established. Meanwhile, the aging of staff with a high level of skills is depleting their numbers, and this is a particularly significant problem for global production. This is a field in which it is desirable to combine simulation, measurement, and other techniques to encourage the formalization of knowledge, or what is often referred to by the term "know-how."

EXAMPLES OF HITACHI'S ACTIVITIES

This section summarizes each of the nine articles in this issue and explains how they relate to Hitachi's activities. Each article describes an example application of simulation, measurement, or production technology, with a particular focus on manufacturing platforms, and also on how they integrate with information and system platforms.

Applications for Simulation Techniques

"Material Property Simulations for Efficient Design of Environmentally Conscious Functional Materials" describes a simulation technique for predicting material properties from first principles at the level of electrons and atoms.

As global environmental problems become more severe, there is an urgent need to develop environmentally conscious materials. In the past, the development of new materials such as these often involved repeated trial-and-error testing of prototypes. However, because this approach was very time consuming, it was considered desirable to shift to an analysis-led approach to material design by using computer simulations to perform design efficiently.

Using anode materials for high-performance lithium-ion batteries, piezoelectric materials that do not contain lead, and recyclable plastics as examples, this article describes example applications for molecular simulation using a combination of analysis techniques to determine the overall behavior of the material at two different scales, namely the use of quantum mechanics to calculate the behavior of electrons and classical mechanics to calculate the behavior of atoms.

"Platform Technology for Computational Fluid Dynamics Supporting Design of System Products—from Power Plants and Industrial Machinery to Home Appliances" describes examples in which large-scale fluid dynamics simulations are used to predict complex fluid phenomena, an application that will be needed in the future.

The pursuit of greater energy efficiency is an important consideration in the development of many different products, from home appliances to power plants and industrial machinery. Pumps, fans, and other fluid devices are used in many of these systems, and computational fluid dynamics (CFD) has for some time been successfully used as a core technology in the design of many products. Ensuring competitive product development in the future will require, among other things, devising new ways of using fluid dynamics in design, and measures aimed at elucidating phenomena that are not amenable to conventional analysis.

This article includes an example of how Hitachi is utilizing collaborations between industry and academia to work on large-scale analyses that use fluid dynamics to study phenomena that could not previously be tackled, and how it is applying multi-objective design optimization and cavitation analysis techniques in its product design.

"Welding Simulation Technologies for Highly Efficient Production of High-quality Social Infrastructure Products" describes welding distortion simulations for large structures.

Large welded structures are used extensively in power plants, industrial machinery, construction machinery, rolling stock, and other types of products, and welding accounts for a large proportion of the overall manufacturing process. Hitachi has developed techniques for improving analysis speed and accuracy, and also a database of material property values that takes account of factors such as material, structure, and environment based on past finite element method (FEM) analyses.

This article describes the state of progress for the technology used in the development of a deformation simulation technique that combines a high level of precision and speed, and examples of its application to the fabrication of large structures.

"Next-generation Inverter Technology for Environmentally Conscious Vehicles" describes the structure of next-generation inverters, and power modules that allow fast and highly efficient switching.

Amid calls for a reduction in carbon dioxide (CO_2) emissions to help realize a sustainable society, use of hybrid electric vehicles (HEVs) and electric vehicles (EVs) is growing. Meanwhile, the construction of large power generation systems is being hastened to increase the amount of power produced from renewable energy sources such as wind and photovoltaic power generation. Small and highly efficient inverter systems will be essential for achieving this low-carbon society.

Inverters are one of the components of the power electronics systems that support this sector, and this article describes analysis and design techniques that use specific technologies needed to reduce inverter size and improve power density, including physical circuit design methods, cooling, and anti-vibration analysis.

Applications for Measurement Techniques

"Lifetime Prediction for Heavy-duty Industrial Lithium-ion Batteries that Enables Highly Reliable System Design" describes a technique for predicting the operating lifetime of lithium-ion batteries with a high degree of accuracy.

The anticipated uses of lithium-ion batteries include energy storage systems such as backup power supplies, and reducing fluctuations in the output of renewable energy generation systems. Being able to reliably predict the lifetimes of the batteries used in these applications makes energy storage systems more affordable and gives greater confidence in the estimated operating life of the systems.

This article describes how experimental measurement techniques and a theoretical model were used to formulate a lifetime prediction equation that incorporates terms corresponding to the square root function law, Arrhenius law, and additive law methods used in the past. It also describes the resulting lifetime prediction technique that considers the number of cycles, operating time, and ambient temperature to improve lifetime prediction accuracy.

"Development of Spin SEM Technology for Observation of Magnetic Domains" describes the electron microscopes used to study various different magnetic materials, including hard disk drives (HDDs) and permanent magnets, with a particular emphasis on spin-polarized scanning electron microscopes (spin SEMs).

By taking advantage of their features, which include being able to study the magnetic structure of a device at the nanometer scale, perform three-dimensional analyses of magnetic orientation, and analyze magnetization and shape information separately, spin SEMs are already being used in applications such as evaluating the shape of storage bits on magnetic media.

This article includes example applications and describes how analysis of a wider range of materials, including permanent magnets, has been made possible by the development of a new mechanism that allows high-temperature observations of a heated sample, and another that shields magnetic stray fields on the sample surface to allow observation of samples with remanent magnetization.

"Low-energy Electron Diffractive Imaging for Three-dimensional Light-element Materials" describes an electron diffraction microscope created by retrofitting an SEM with a high-resolution imaging function that reconstructs the phase information from a diffraction pattern in order to allow diffractive imaging to be used with a low-energy electron beam.

Electron microscopes are already used in the development of materials and devices, particularly in semiconductor manufacturing, and they have also been used extensively in research aimed at identifying the structure of dislocations in metals. However, developments in recent years, such as the extensive use of carbon-based materials as battery electrodes, including in lithium-ion batteries, have seen growing demand for analysis of lighter element materials. This article describes how images of the atomic structure of single-wall carbon nanotubes (comprising a single loop of graphene sheet) were obtained from their diffraction pattern using computer processing.

Applications for Production Technologies Using Statistical Models

"Production Control System to Visualize Future Effects by Production Trouble" describes a production control system able to make highly accurate predictions of the variations in production volume that result from the sort of problems that occur in a supply chain, such as component shortages or equipment failure.

In recent years, there has been a need for supply chains with the flexibility and resilience to minimize the impact when unexpected problems or disasters occur at the production sites and logistics operations that have spread throughout the world in conjunction with the globalization of business. This article describes a production control system that uses a statistical model for the highly accurate prediction of the variations in production volume that will occur in the manufacturing process after a problem occurs.

Applications for Information and IT

"IT Resource Management Technology for Reducing Operating Costs of Large Cloud Data Centers" describes IT resource management technology for the administrators who operate and manage cloud data centers, which are becoming increasingly larger.

Data centers provide the platform for cloud computing. The main problems facing these data centers in recent years have been the difficulty of centralized management of increasingly large data centers, the growing workload being placed on individual administrators due to the specialized nature of advanced management skills, and the increasing amount of time spent on coordinating administrators of different layer.

This article describes Hitachi's work on management repository technology that allows centralized administration of large-scale IT resources, root cause analysis technology that formalizes the advanced know-how of administrators in the form of structured knowledge, and virtual server and storage administration coordination technology that automates storage configuration and reduces the workload associated with coordinating different administrators.

PLATFORM TECHNOLOGIES THAT SUPPORT COMPLEX AND DIVERSE SYSTEMS

This article has described the future outlook for common platform technologies used in product development from a global and systems perspective.

Success in global competition requires a wide range of platform technologies that can predict and control various different phenomena in diverse and complex product environments, and also the ability to integrate these technologies. Technologies that can take on the challenges and take account of the risks associated with supporting complex and diverse systems can be recognized as the common platform technologies that will generate new value in the future.

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