May 2024 Technical Information

Innovation for Advancing with Customers: Connective Industries

Research & Development

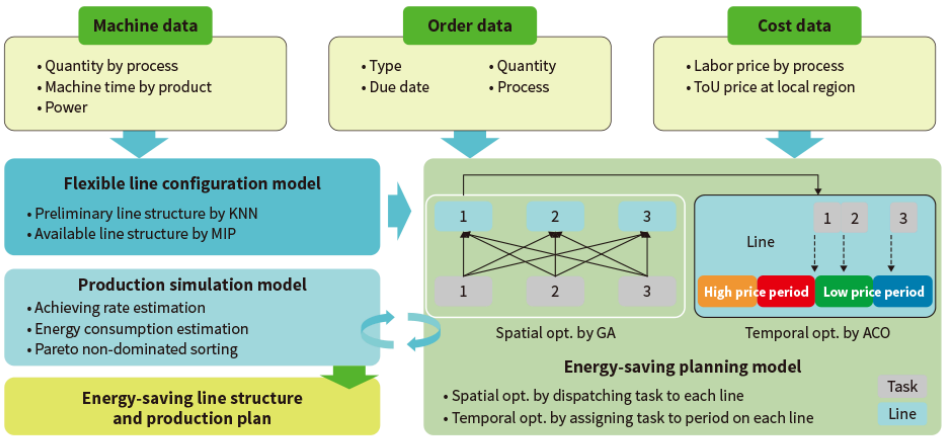
#Healthcare, QoL #Innovation Creation #Co-creation and Open Innovation #Sustainability #Generative AI #Robotics #IoT/Data Utilization #Research & Development

1. Flexible and Energy-saving Production Planning Solution in Industrial Equipment O&M

Production planning has always been an important tool in the field of manufacturing as it can significantly help improve production efficiency by dispatching production tasks on existing equipment. With the growing trend towards energy-saving and flexible production modes in China, it places a demand on the refining operation of equipment in production activity, which traditional production planning is unable to support.

As an improvement, Hitachi proposes a flexible and energy-saving production planning solution. This solution consists of a set of planning models for a spatial-temporal production planning with integrated equipment operation factors, including a flexible line configuration model, a production simulation model, and an energy-saving planning model. Using order, machine, and cost data, this solution outputs a suitable line structure and a corresponding production plan that achieves the target completion rate and minimizes energy consumption in parallel. Around a 2.7% reduction in energy costs could be achieved under experimental conditions. This solution is aimed at energy-intensive industries such as steel or petrochemicals, and is expected to work as an independent service or a system function module.

[01] Solution framework



ToU: time-of-use pricing
KNN: k-nearest neighbor
MIP: mixed integer programing
GA: genetic algorithm
ACO: ant colony optimization

2. Development of Design for X-ray Therapy Machine Easy on Both Technicians and Patients

The ability of X-ray cancer therapy to treat tumors without surgery makes it a comparatively less invasive treatment for patients, helping to maintain and improve patient quality of life (QoL) during and after therapy. Hitachi has developed the OXRAY linear accelerator system for X-ray therapy, which combines high accuracy with high throughput (sales commenced on July 19, 2023).

Hitachi utilized surveys of hospital facilities in the design of the machine from the early stages of development, using them as a basis for identifying issues relevant to patient care and to the machine's throughput and ease of use. Along with a hardware design that incorporates a proprietary gimbal function and two-axial rotation function for precise X-ray delivery, Hitachi sought to design the gantry in a way that feels less confining to the patient while also conveying a sense of freshness and reliability. In the software design, operation was unified by integrating systems that were previously separate. Screen layouts, meanwhile, were designed for reliability and efficiency in the presentation of the information that matters for each patient.

[02] OXRAY linear accelerator system

Through a total design approach to both the machine and its software, Hitachi can supply therapy machines that consider the needs of both patients and technicians, helping to reassure the patient and provide less stressful operation for the technician.

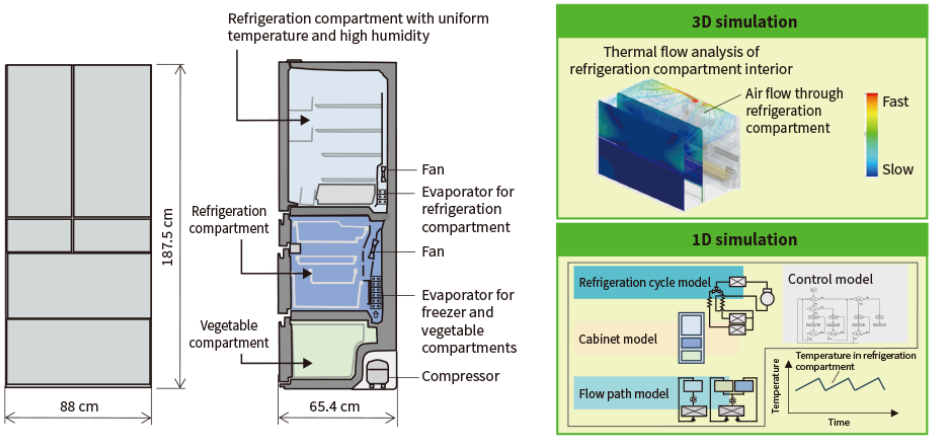
3. Highly Efficient Cooling System for Slim Refrigerators with Wide Profile

Hitachi has used a combination of three-dimensional (3D) and one-dimensional (1D) simulation to develop a highly efficient cooling system for a slim refrigerator with enhanced ease-of-use that features a large 88-cm width, but is only 65.4 cm deep.

While large refrigeration compartments with wide profiles are prone to temperature inconsistency, efficient cooling is achieved by supplying a large flow rate of humid air from a dedicated evaporator. Controlling the temperature of the evaporator based on the refrigeration compartment cooling requirements enhances energy efficiency performance. It also chills the shelf spaces where food is stored at a uniform temperature and high humidity (approximately 2°C and 80% respectively)*. These storage conditions are a feature of the new refrigerator model launched by Hitachi Global Life Solutions, Inc. in March 2023 (the R-GXCC67T GXCC type refrigerator) in the form of a moisture cooling feature that maintains the freshness of cooked food regardless of where it is placed on the shelves.

* Mean humidity in shelf space of approximately 400 g of leafy vegetables stored for 24 hours.

[03] Refrigerator design and simulation used in development



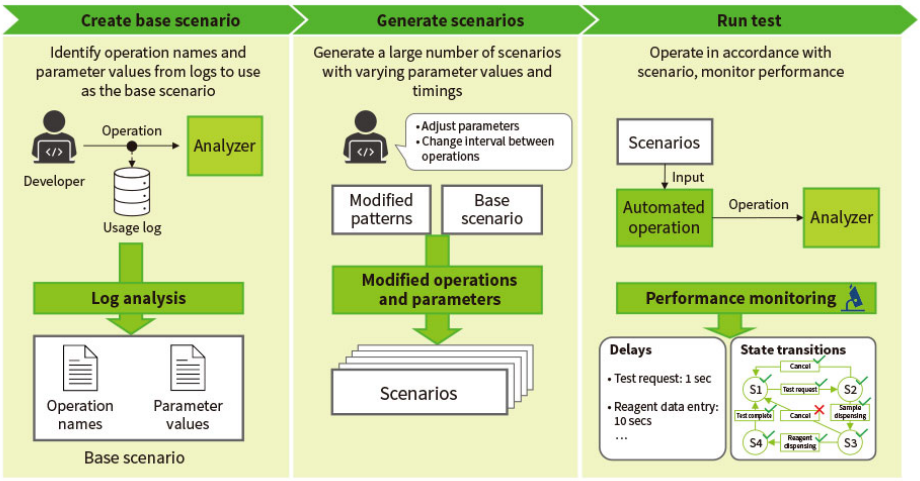
4. Development of Software Verification Automation for Improving Reliability of Clinical Analyzers

Hitachi has developed a labor-saving technique for automating the verification of non-functional requirements in clinical analyzers made by Hitachi High-Tech Corporation.

The technique identifies violations of non-functional requirements by operating the analyzer automatically in accordance with scripted scenarios and tracking its response times, state transitions, and other performance criteria. The base scenario is created from an analysis of usage logs, with a large number of additional scenarios then being generated by modifying operation timings and parameters. Using these scenarios to perform automated testing allows a large amount of verification work to be done with minimal labor while also detecting rare problems that only occur under specific timing or operational conditions. Use of the technique helps to improve the quality of clinical analyzers through the prevention of problems such as slow response times.

In the future, Hitachi intends to reduce workload requirements further by linking the technique to the continuous integration/continuous deployment (CI/CD) system to enable earlier detection of defects.

［04］Software verification automation for improving reliability of medical analyzers



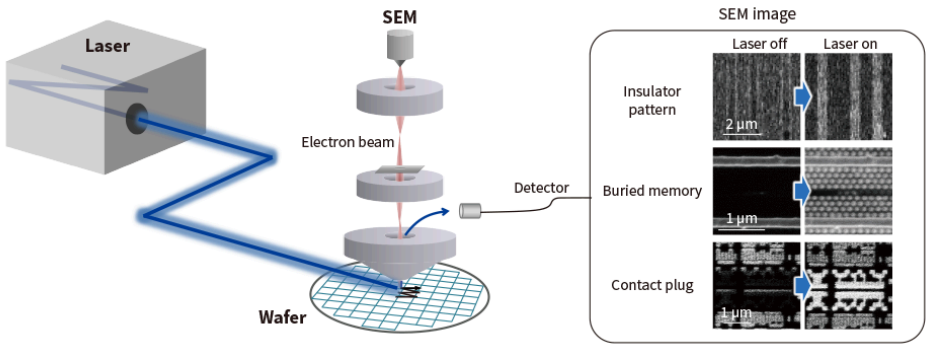
5. In-line Measurement of Electrical Properties for Reliable Production of Advanced Semiconductor Devices

Semiconductor devices are considered the cornerstone of the modern information society. The importance of ensuring their stable supply has grown with advances in artificial intelligence (AI) and progress toward digital transformation (DX). For reliable production, scanning electron microscopes (SEMs) have traditionally been used for metrology and inspection of the nano-scale patterns fabricated on wafers to make the devices. However, the shift to 3D device structures and the wider range of materials being used in recent years has led to an increase in instances where conventional dimensional metrology fails to detect defects in materials or circuits below the wafer surface. This has led to a demand for new metrology and inspection techniques.

To meet this new demand, Hitachi is developing a laser-assisted SEM (LA-SEM) that irradiates laser onto the wafer while probing it with an electron beam. By evaluating the response to irradiation of electron beam and laser, electrical and material properties of the patterns and circuits fabricated can be measured. Using the LA-SEM, we have demonstrated enhancement in material contrast and visibility of buried structures, as well as contrasts reflecting electrical properties of circuits below the wafer surface.

To enhance the accuracy of the measurements, Hitachi is developing a model that converts the contrasts to electrical properties while taking into account the structural information of the device. Using LA-SEM as an in-line tool for the measurement of electrical and material properties, Hitachi will contribute to the reliable production of advanced semiconductor devices.

［05］Diagram of laser-assisted SEM and examples of contrast-enhanced SEM images

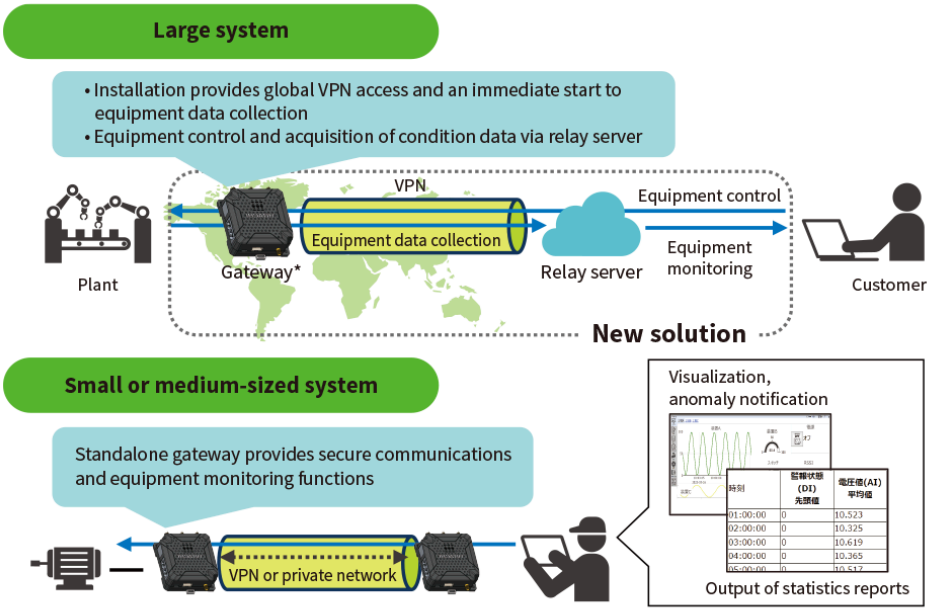


6. Scalable Remote Equipment Monitoring Solution that Facilitates On-site System Configuration

Industrial systems that utilize data collected from on-site equipment for remote maintenance and control optimization have attracted attention in recent years as a means of improving workplace productivity and maintenance efficiency. Unfortunately, this has raised issues with the amount of system design and configuration work associated with installing dedicated equipment for site monitoring or with adopting third-party services for the centralized monitoring of multiple sites.

In response, Hitachi has developed a technique for setting up remote equipment monitoring in a way that suits the size and configuration of the system. All that is required is to install a pre-configured industrial gateway at the site being monitored. When used to monitor equipment at a site, the standalone gateway functions can perform data collection, statistical processing, visualization, and alarm notification based on the site's system configuration. For centralized monitoring of multiple sites, the gateways connect to a server to automatically establish secure pathways for control communications over a virtual private network (VPN). This communication pathway can be used for collecting and accessing equipment data and for the remote control of on-site equipment. This feature makes it easy to establish remote equipment monitoring regardless of system size.

[06] Scalable remote equipment monitoring solution that facilitates on-site system configuration



* CPTrans-MGW (CP-QGWG-E2S-1) of Hitachi Industrial Equipment Systems Co., Ltd.

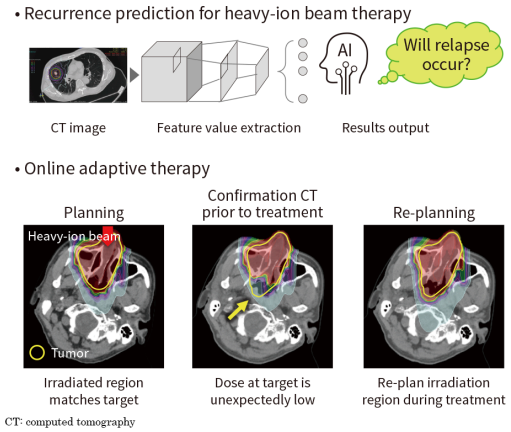
7. AI and Digital Technologies that Help Improve Patient QoL by Personalizing Heavy-ion Therapy

Hitachi is participating in joint research aimed at personalizing the entire process of heavy-ion therapy for patients, from deciding it is needed to its delivery. Its partner, Gunma University, has extensive clinical experience, and the research work involves the development of an AI technique for predicting treatment efficacy and an online adaptive therapy system that responds promptly to day-to-day changes in the patient's body.

The AI efficacy prediction is intended for use with non-small cell lung cancer. It was developed by constructing a model to predict whether the patient will suffer a recurrence after heavy-ion therapy based on three cross-sectional images of the tumor. As the technique uses information about the patient prior to treatment as an input, it can deliver efficacy predictions pre-emptively to assist doctors and patients in the selection of treatment method.

Development of the online adaptive therapy system, meanwhile, involved the creation of a workflow for heavy-ion therapy that could adapt promptly to day-to-day changes in the patient's anatomical condition. Along with adopting the same system configuration for shortening treatment time that is used on proton beam therapy systems, the clinical experience of Gunma University was utilized in developing a decision support technique for deciding whether to proceed with treatment plans based on dose indexes. This enables efficient workflows to be determined.

[07] AI and digital technologies for personalization of heavy-ion therapy



CT: computed tomography

8. Highly Reliable Insulation for Harsh High-altitude Environments

There has been an acceleration in the electrification of transportation and in the adoption of hydrogen as part of efforts toward achieving carbon neutrality in 2050. One of the issues with electrifying aviation, however, has been how to improve the high-altitude reliability of the insulation used in electric propulsion components. In response, Hitachi has developed insulation technology that can cope with altitudes of 12,000 m.

The silicone gel widely used as an electrical insulator in power modules has a low elastic modulus and high tolerance for thermal stress. Unfortunately, its insulation characteristics degrade under high-altitude conditions as stresses caused by air pressure differences lead to deformation and the expansion of residual micro-voids in locations such as the interfaces between insulator layers. Accordingly, Hitachi devised a material selection strategy that focused on elastic modulus and adhesive strength to prevent void expansion and delamination. In sample testing, the use of a silicone coating with an elastic modulus higher than that of silicone gel successfully passed a DO-160G air pressure cycle test for aeronautical environments.

In the future, Hitachi will contribute to reducing life cycle costs through longer product life by utilizing this insulation technology to improve the environmental durability and insulation reliability of electric propulsion components and industrial transformers.

[08] Insulation reliability for harsh high-altitude environments

Insulator	Silicone gel Soft & low adhesion strength	Silicone coating Hard & high adhesion strength
Elastic modulus/Adhesion strength (Target: > 0.25 MPa, estimated stress at 12 km altitude)	0.0006 MPa / N.A*1	1.0 MPa /1.5 MPa*2
Tolerance for air pressure cycle (Target: > 30 cycles, estimated air pressure at 12 km) air pressure cycle test	Five cycles	> 60 cycles (PDIV > 10 kV)
Configuration of test sample Electrodes Insulation distance 1.0 mm Insulator Silicone gel, silicone coating	After air pressure cycle test Exterior (plan view) Air pressure (hPa) 194 (12 km) 1,015 (Altitude: 0 m) 10 min (1 cycle) Time (min) Air pressure cycle test	Air bubble Electrode • Micro-voids enlarge between electrodes during pressure cycles • Insulation breakdown five cycles after insulation distance was shortened	No change in exterior Electrode • No air bubble formation • No insulation breakdown in air pressure cycle test

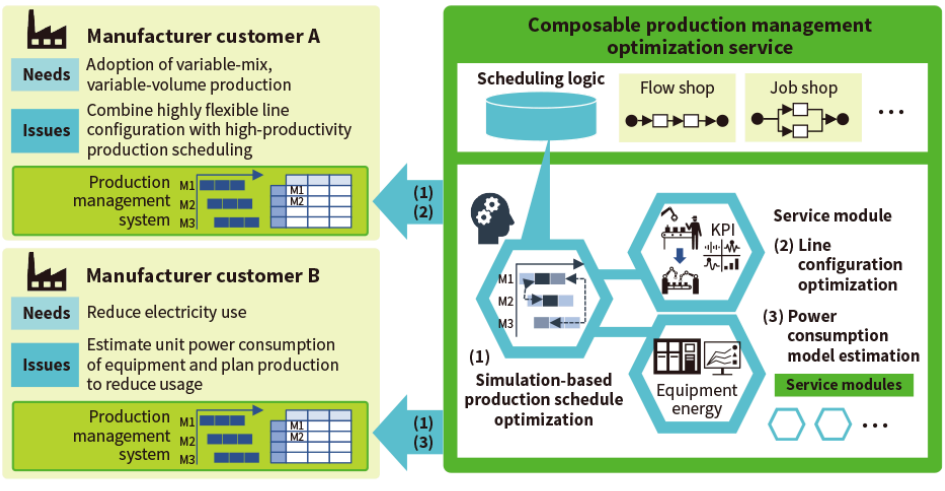
PDIV: partial discharge inception voltage
*1 Measurement is not possible below 0.1 MPa
*2 Adhesion strength for Al electrode

9. Development of Composable Production Management Optimization Service

Along with greater diversity in consumer preferences and global parts shortages, the manufacturing industry is seeing greater demand for variable-mix, variable-volume production. This has also been accompanied by a need to reduce electricity consumption at factories as part of efforts to achieve carbon neutrality. Among the challenges for achieving these goals are how to design production lines to facilitate variable-mix, variable-volume production by combining productivity with flexibility, how to perform rapid production scheduling to keep up with fluctuating demand, and how to schedule production in a way that minimizes electricity use to assist the transition to carbon neutrality. To address these issues, Hitachi has developed a composable production management optimization service that delivers functions based on customer need through the flexible combination of different optimization services.

The service overcomes the challenges faced by customers seeking to achieve carbon neutrality and adopt variable-mix, variable-volume production. At its core is simulation-based production schedule optimization that is equipped with scheduling logic to suit flow shop and various other line configurations. This enables rapid production scheduling. It also works in tandem with a technique for optimizing line configuration that handles worker and equipment allocation and an estimation technique for power consumption models that estimates the unit energy consumption of equipment.

[09] Block diagram of composable production management optimization service



KPI: key performance indicator

10. Robotics Automation for Construction Workplaces

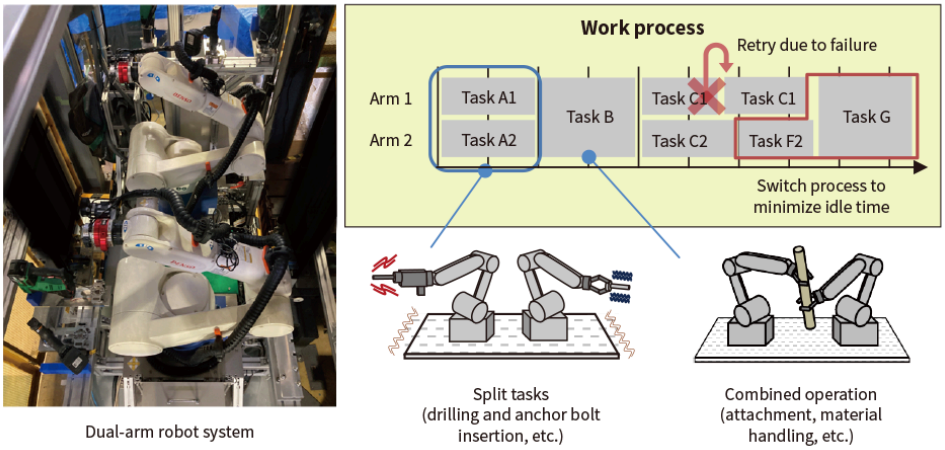
The construction industry is continuing to investigate the use of robots as a means of saving labor and to prevent falls when working in high places. However, improving work efficiency is important when seeking to use robots for heavy work such as putting in anchor bolts* at high locations where footing is poor. This is because such tasks tend to result in frequent retries.

Hitachi has developed a dual-arm installation robot system with a high success percentage for work in unstable locations and the ability to switch processes when an error occurs, automatically and in real time.

The system is equipped with robot control techniques that use machine learning. It can insert anchor bolts even where footing is poor and it is difficult to accurately measure the position of the holes in the concrete wall. Even if a work error occurs for one of the robot arms, the loss of work efficiency can be kept to a minimum and the additional time required for retries can be reduced by automatically switching to dual-arm operation.
In the future, Hitachi intends to contribute to safe and highly efficient workplaces by conducting field tests to verify the benefits of this control technique for installation robots.

* Anchor bolts that are inserted into concrete to serve as mountings for pipes or other fittings, structural elements, or equipment.

［10］Newly developed dual-arm robot system and technique for real-time process switchover when an error occurs



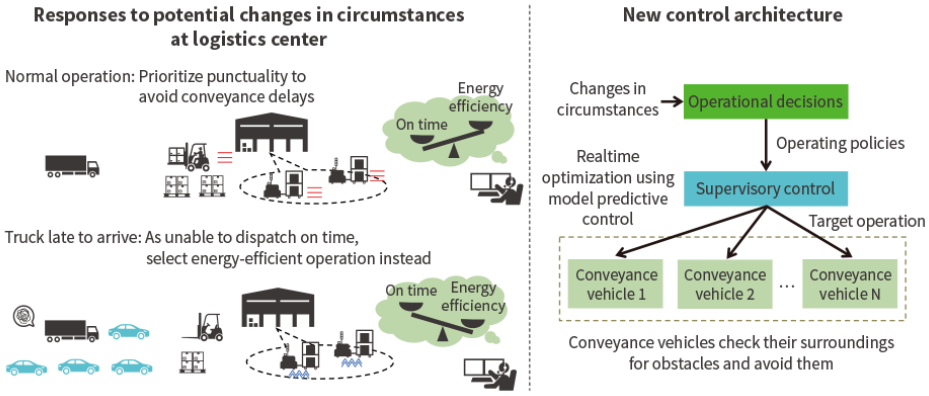
11. Application of System Control with Model Predictive Control to Goods Conveyance

Advances in digitalization call for the interoperation of multiple systems, including the use of techniques that automatically adjust how systems are operated based on the circumstances. To address this need, Hitachi has developed model predictive control that can be executed in real time using evaluation routines that it auto-generates and which specify the required operation methods. This auto-generation of control operations is done by mathematical optimization, so model predictive control does not require case-specific operation design. The technique is suitable for a wide range of uses, extending from overall control of multiple systems to controlling the operation of individual systems.

To verify the utility of the new technique in a simulator, Hitachi implemented an example application involving a goods conveyance control system for a logistics center that was able to modify operation plans in response to changing circumstances, such as delays in truck arrivals. The system performed supervisory control using evaluation routines that considered multiple KPIs and by doing so was able to generate operational plans automatically based on changing circumstances. Moreover, control of the individual conveyance vehicles included automatic avoidance of collisions with obstacles in their vicinity while successfully carrying out the instructions of supervisory control. It is anticipated that this will provide safe and efficient operation without a heavy design workload.

In addition to deploying the technology at actual logistics centers, Hitachi also plans to investigate extending its use to other systems such as those for local transportation.

［11］Control architecture able to adapt with flexibility to changing circumstances



12. On-site Degradation Assessment and Life Estimation for Polymers

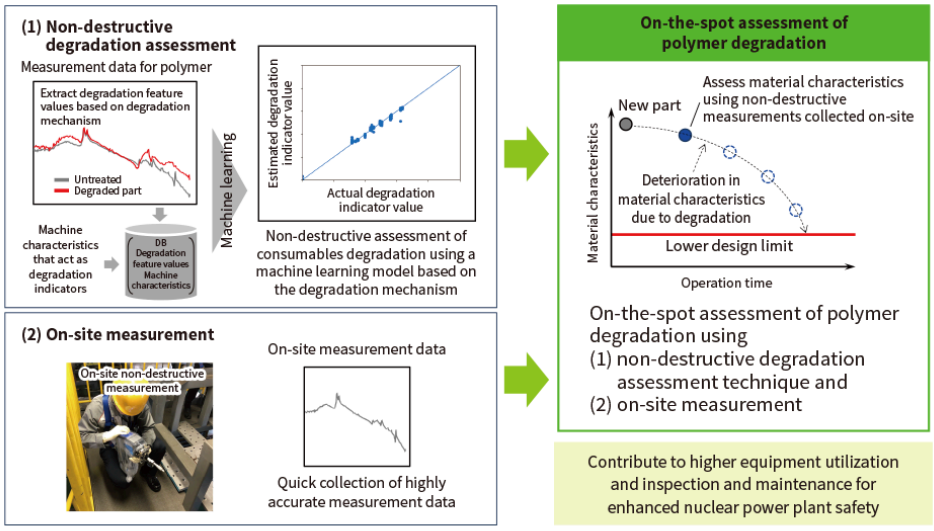
The Japanese government has set a target of 20 to 22% for the contribution of nuclear power to the national power supply. In addition to restarting existing facilities, increasing plant utilization without compromising safety will also be important for achieving this target. One effective way to improve utilization is to reduce inspections and the amount of replaced equipment while still maintaining equipment performance and safety to shorten routine inspection times. To enable this, Hitachi has developed a diagnostic technique for the polymer consumables that are often replaced as part of a routine inspection. This involves performing non-destructive on-site measurements on these materials to assess the extent of degradation and estimate their remaining life.

The technique assumes that, in addition to heat and stress, the degradation mechanism for these polymers involves multiple factors that interact with the radiation damage that is an issue unique to nuclear power plants. By establishing procedures for eliminating external factors likely to interfere with on-site measurement, it was demonstrated that the technique should be able to provide quick and quantitative on-the-spot assessments.

By leveraging its materials knowledge to measure, collect, and evaluate data on polymer degradation, Hitachi intends to play its part in raising equipment utilization and contribute to inspection and maintenance for enhanced power plant safety.

(Hitachi-GE Nuclear Energy, Ltd.)

［12］On-site degradation assessment for polymers at nuclear power plants



DB: database

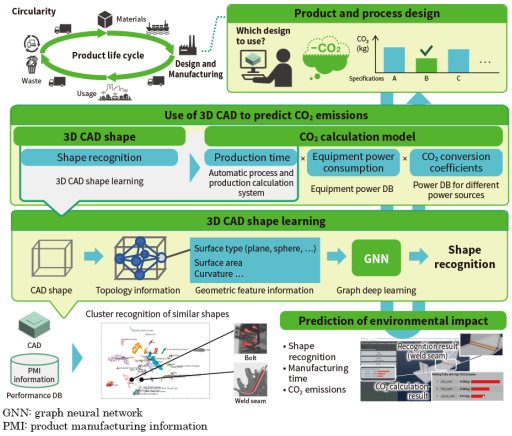
13. Prediction of Product's Environmental Impact from 3D CAD Data

Developing products with a low environmental impact calls for improvements in design based on a life cycle assessment (LCA) of the product's environmental indicators. As LCA is typically performed by an environmental assessment expert after product design is complete, it cannot be done during design and so can result in rework. To address this, Hitachi has developed a product design technique that can perform an automatic LCA as the product is modeled on a three-dimensional computer-aided design (3D CAD) system.

Performing an automatic LCA from the 3D CAD involves obtaining the data needed for assessment from a large database of design requirements and environmental requirements and then using this data to predict the environmental impact by means of CAD shape recognition. Hitachi has achieved the shape recognition accuracy required by LCA by using a proprietary technique for graph deep learning that can be trained directly on CAD shapes without the need for conversion, as opposed to the previous learning methods that use transformed data such as point clouds or meshes.

Use of this technique to undertake product design and LCA in parallel will enable the development of products with a low environmental impact with low effort and cost.

[13] Use of 3D CAD to predict CO_2 emissions



GNN: graph neural network
PMI: product manufacturing information

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