Hitachi Review
Volume 64 Number 7 August 2015

HITACHI
Inspire the Next

Construction Machinery and Mining Solutions for Increasingly Diverse Needs

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From the Editor

While the market for construction machinery is subject to fluctuating demand, being highly responsive to trends in the global economy, demand is expected to continue growing in the medium to long term based on a background of development in emerging economies, including rising populations and urbanization. Meanwhile, with demand for resources forecast to continue growing steadily, an increasing requirement for more productive mining machinery is also anticipated.

The Hitachi Construction Machinery Group sees its mission as the timely supply of products that accurately reflect the increasingly diverse needs of customers in the global market by keeping pace with rapidly changing social and business conditions. Along with supplying machinery that has excellent performance and reliability, Hitachi also seeks to supply products and services that are a close fit with the challenges faced by customers in areas such as safety, the environment, and economics.

To fulfill this mission, we are taking steps to differentiate our products and services in our role as part of the Hitachi Group and its core Social Innovation Business by drawing on synergies with research and development laboratories of Hitachi, Ltd. and its wide range of businesses, which encompass the energy, railway, automotive, and information technology (IT), and other sectors.

This issue of *Hitachi Review* describes some of these initiatives.

Because improving the productivity of large mining machinery at mine sites that operate day and night is a key challenge, we are working to enhance the functions of fleet management systems that equip vehicles with sensors and utilize information. We are also boosting our initiatives for adopting IT with a view toward using construction machinery in “information-oriented construction.” Having led the world by launching our Global e-Service remote monitoring system for machinery, we are now proceeding with new developments. A new service called ConSite provides a framework for supplying a bundle of services together with detailed information to customers all over the world.

We are developing construction machines that comply with stringent environmental standards to be more conscious of the environment. Articles in this issue describe the ZAXIS-6 Series of hydraulic excavators that comply with the Tier 4 emissions regulations, and a hybrid wheel loader that is the first in the world (based on Hitachi Construction Machinery research) to feature regenerative braking. Another example is Hitachi Construction Machinery’s very large mining dump trucks, which incorporate new functions designed to improve both productivity and safety. Other articles describe the use of simulation to help with development efficiency and reliability and profile our global production activities.

I hope that this issue of *Hitachi Review* will help you learn more about our construction machinery business in its role as part of Hitachi’s Social Innovation Business.

Editorial Coordinator,
“Construction Machinery and Mining Solutions for Increasingly Diverse Needs” Issue

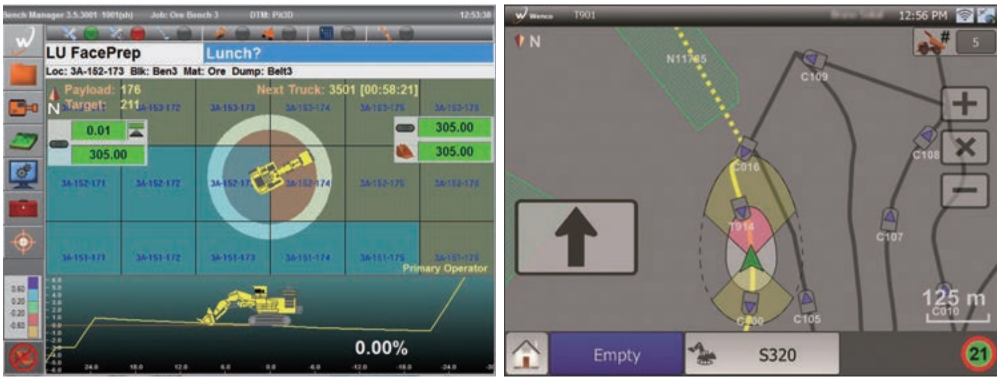
Hideshi Fukumoto
Executive Officer
General Manager of Research Div.
Hitachi Construction Machinery Co., Ltd.

Construction Machinery and Mining Solutions for Increasingly Diverse Needs

Contents

Construction Machinery and Mining Solutions for Increasingly Diverse Needs

Construction and mining machines are used around the world for such tasks as resource development, social infrastructure development, and disaster reconstruction.
These machines are also being called on to overcome new challenges against a background of changes in the global economy and structure of society.
Through all of this, Hitachi has continued striving to enhance the functions and performance of its construction and mining machinery to keep pace with the evolving needs of different times, countries, and regions.
Around the world, Hitachi is helping build a prosperous future by supplying advanced products, together with the associated services and solutions, to overcome the challenges facing society, reducing the load on the environment while also improving efficiency and productivity.

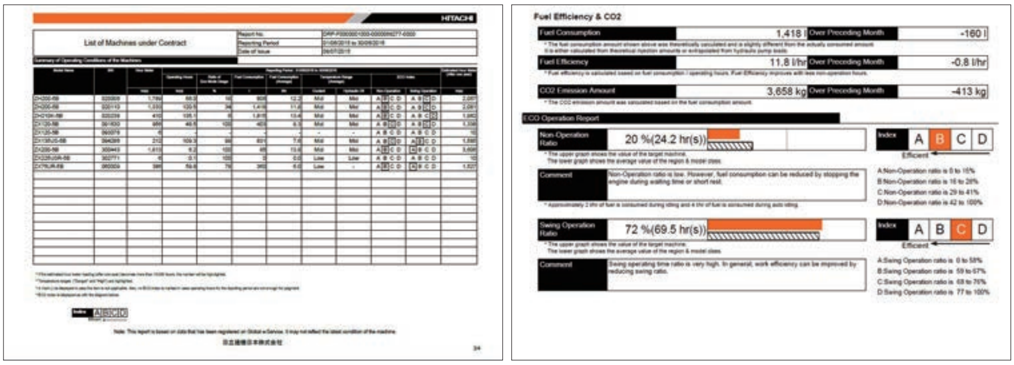


Mining industry fleet management system

Ultra-large dump truck, EH5000AC-3

Ultra-large hydraulic
excavator, EX8000

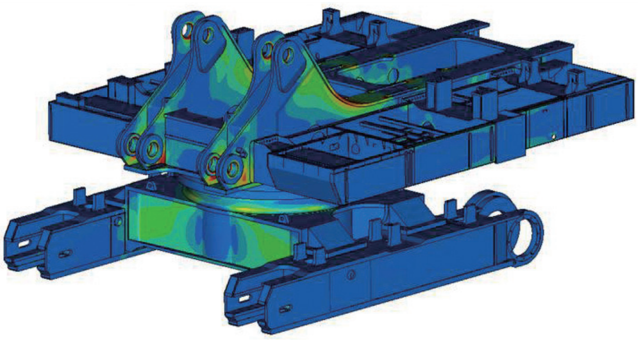
Global production infrastructure, including plants in Russia (left) and Brazil (right)

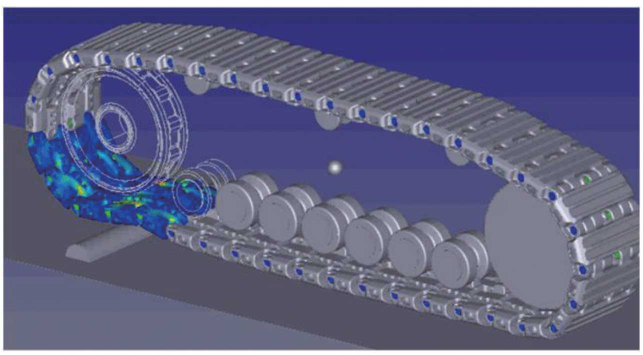


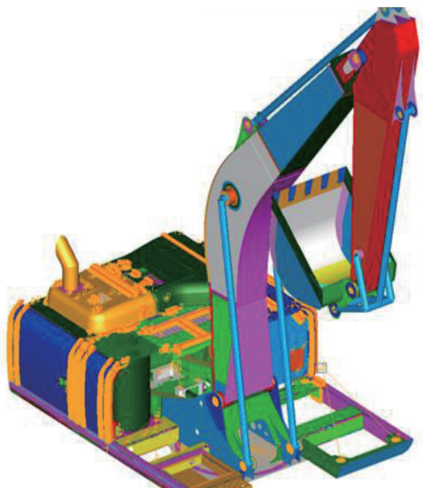
Data Report Service provided as part of the after-sales service program for construction machinery

Hydraulic excavator, ZAXIS-6 Series

Hybrid wheel loader, ZW220HYB-5B







Simulation technology that supports product development

Expert Insights

Overcoming Limited Resources

Takafumi Tsujimoto

Executive Director, Member of the Board (Metal Strategy & Exploration Unit)
Japan Oil, Gas and Metals National Corporation (JOGMEC)

Completed Graduate School of Engineering (Geophysics), Kyoto University
Joined the Metal Mining Agency of Japan (MMAJ) in 1980 (JOGMEC was established in 2004 through the integration of Japan National Oil Corporation and MMAJ). Over the past 35 years he has been involved with development and innovation in mineral exploration projects, both domestically and abroad, and metal mining and exploration technologies (especially exploration technology). Past appointments include General Manager of the MMAJ Santiago Office in Chile and of the MMAJ Lima Office in Peru. In recent years, he has led a resource evaluation project regarding deep-sea mineral resources in both Japan's exclusive economic zone (EEZ) and the high seas, and also the development of mining technology for deep-sea mineral resources. Since 2014 he has been an Executive Director and Member of the Board of JOGMEC.

The 1972 report of the Club of Rome made the case that, because finite resources place a limit on growth, at some point growth must come to an end. While the question of what to do when non-renewable resources such as fossil fuels run out has come up again and again since the two oil shocks in the 1970s, the theory of peak oil that has circulated widely in recent years has been dampened by the shale revolution in which technical innovation has enabled the development of unconventional resources. Similarly, for all that metals can be recycled, the quantity of underground mineral resources is finite and overcoming limited resources requires ongoing cost reductions achieved through technical innovation.

Using as an example the South American nation of Chile, where one-third of the world's copper is produced, a series of large open-pit copper mines have been developed since the 1990s, and extensive use has been made of the solvent extraction and electrowinning (SX-EW) technique, which produces copper cathode directly from ore by spraying sulfuric acid over the piled ore to dissolve it (heap leaching), separating copper ion from others (solvent extraction) and then using an electrochemical process to obtain the metal (electrowinning). Recently, bioleaching has been applicable to take advantage of the ability of bacteria to dissolve ores that would otherwise be difficult to dissolve. Unfortunately, as more copper ore is mined, production conditions become progressively more difficult. The depth of exploitable ore gets deeper, ore grade gets lower, mine developments are located more remotely, the level of impurities in the ore rises, and so on. Because the most exploitable deposits are mined first, it is self-evident that exploration, development, and production cost will all rise over time. In Chile, meanwhile, obtaining water for use in mines places them in competition with other industries, and fulfilling the rapidly growing demand for electric power presents a difficult balancing act. The only way to overcome these various problems is through technological innovation. Mine sites present a large number of technical challenges (needs).

On a different note, once every two years Chile hosts EXPOMIN, a large trade show for the mining industry. With regard to construction machinery, although Japanese manufacturers can sometimes be found at the world's mining industry trade shows, unfortunately it is rare to see Japanese products at such events. At the oil and gas division of Japan Oil, Gas and Metals National Corporation, we have established a technical solutions project that seeks to utilize the advanced technologies of Japanese companies to solve the technical challenges facing such organizations as the state-run oil companies of oil-producing nations. Our aims are both to help create new business opportunities and to strengthen relationships with oil-producing nations. In the case of metals, meanwhile, because most production companies are privately run, even in emerging nations, an approach based on resource diplomacy often presents difficulties. Nevertheless, given the advanced technical capabilities of Japanese companies, I believe that even companies that have not been involved with the mining industry in the past have the potential to make major contributions to resolving the technical challenges that mine sites face. Especially now, with the depression of metal prices, I see scope for Japanese companies to take on the task of overcoming these various technical challenges. This, I believe, is how we can overcome the "The Limits to Growth" resulting from limited mineral resources.

Technotalk

Utilizing ICT and the Combined Power of the Group to Help Build a Prosperous Society

Toshihiro Oono Vice President and Executive Officer, CTO, President of Development & Production Group, General Manager of Development Group, and General Manager of Environment Policy Div., Hitachi Construction Machinery Co., Ltd.

The construction machinery that underpins the progress of society has undergone a variety of technical innovations in the past. In recent years, meanwhile, there have been demands for further gains in productivity together with operational and safety improvements from customers such as the mining industry, which is facing an increasingly difficult business climate, and at construction workplaces beset by concerns about staff shortages. Hitachi Construction Machinery is creating new value in construction machinery by utilizing ICT, sensor, and other technologies where advances are being made, including functions for optimizing maintenance and helping operators drive the machinery. In this article, Toshihiro Oono, Vice President and Executive Officer of Hitachi Construction Machinery Co., Ltd. describes the development of technologies for achieving ongoing advances and the company's development organization that meets regional needs.

Uses for ICT that Boost the Productivity of Construction Machinery

—While the marketplace for construction machinery faces increasing uncertainties that include cheap oil and concerns about economic recessions in Europe and China, what do you see as the important factors for achieving ongoing business growth?

Oono: While the market for construction machinery used for tasks such as urban development, infrastructure construction, and resource development will continue to experience industry growth in the medium to long term, it is affected by global economic trends and there is no prospect of a rapid rise in demand in the near future. Meanwhile, along with these circumstances, demands also include reducing the load on the environment and enabling customers to produce more efficiently so they can cut costs. The thing that Hitachi Construction Machinery Co., Ltd. emphasizes to increase its presence is to earn the trust of our customers by expanding services that utilize information and communication technology (ICT) to encompass the entire machine lifecycle from finance to after-sales service and resale, while also seeking to differentiate ourselves by providing our construction machinery with added value that makes use of advanced technology. "Reliability and differentiation" are the key words of our GROW TOGETHER 2016 Mid-term Management Plan that commenced in FY2014 and these are important elements in working toward our 2020 VISION mid-term management vision.

While construction machinery has achieved a degree of maturity in terms of the functions it incorporates to carry out various work, there remains scope for the development of technology in areas such as reducing the load on the environment, improving safety and reliability, providing driving assistance, and improving operator productivity. In these areas, we are striving to develop and supply construction machinery that creates value for customers not only by using the technologies we have built up for ourselves, but also by taking advantage of the technologies and advanced research and development work that the wider Hitachi Group has acquired through its involvement in a diverse range of businesses.

—Can you give us some specific examples of what you mean by services that utilize ICT?

Oono: We fit communication devices into our construction machines and operate our Global e-Service, which performs remote management of operational and location data in realtime in a wide range of countries and regions. This helps minimize faults and the consequent work delays by using the collected information as a basis for undertaking maintenance, spare parts procurement, and other such tasks at the appropriate timing.

We used this Global e-Service system to introduce the ConSite* suite of services throughout the world in April 2014. In addition to sending regular reports containing operational data from construction machinery to customers, the service also sends emergency reports if it detects a change in a machine that could potentially lead to a fault. This helps prevent machines from going out of service and enables a quick recovery when problems do occur.

Because construction machines are part of a customer's plant and equipment, it is important to consider how to improve availability and reduce costs over the entire machine lifecycle. Along with supplying highly reliable machines, we are also putting effort into utilizing Hitachi's expertise in ICT to identify the warning signs of problems at an early stage and to advise customers on the appropriate maintenance to perform. In addition to improving availability by avoiding machines unexpectedly going out of service, this also reduces total lifecycle costs by extending product life.

In the future, we will be able to collect more data of different types by expanding the scope of communications and sensing. We are currently working with research and development divisions of Hitachi, Ltd. to find techniques for analyzing huge quantities of collected operational data in order to provide customers with more useful information, such as warning sign diagnoses.

New Value Generated by Collaboration within Hitachi

—I understand that the operational data collected via Global e-Service and other means is also put to use in the development of construction machinery. What can you tell us about that?

Oono: We are working to develop better construction machinery that takes account of operational data and the latent needs of customers. In the case of the ZX-6 Series of hydraulic excavators currently under development, for example, in addition to seeking to improve reliability, durability, and ease-of-maintenance as we have on past models, we are also striving to reduce fuel consumption.

The EH-3 Series dump trucks, which have an alternating-current (AC) drive that uses AC motors powered by electricity generated by the engine to drive the vehicle, achieve precise controllability and a high level of traction and braking by using a highly responsive Hitachi insulated-gate bipolar transistor (IGBT) inverter and an AC drive with control software jointly developed within Hitachi. The latest model in the series incorporates sensors that provide feedback on the status of the vehicle body and control equipment with enhanced performance together with a ride stability control system that minimizes slip, tire lock, longitudinal pitching, and side slip even when driving over rough roads. Along with providing smooth driving, this also helps boost productivity by enabling the dump trucks to be used in poor weather conditions.

We are also working on adopting hybrid drive in construction machinery to reduce fuel consumption and carbon dioxide (CO_2) emissions. We released the ZH200-A hybrid hydraulic excavator in 2011 followed by the even more fuel-efficient ZH200-5B in 2013. We developed an industry-first prototype hybrid wheel loader in 2003 and have since been working on research and development with a view toward commercialization. Like the dump truck with AC drive, the hybrid wheel loader uses the engine to drive a generator and supplies the generated electric power to the traction motors that drive the vehicle. Because this eliminates the need for a torque converter and

* ConSite is a trademark of Hitachi Construction Machinery Co., Ltd.

Toshihiro Oono

Vice President and Executive Officer, CTO, President of Development & Production Group, General Manager of Development Group, and General Manager of Environment Policy Div., Hitachi Construction Machinery Co., Ltd.

Joined Hitachi Construction Machinery Co., Ltd. in 1979 after graduating from the Department of Mechanical Engineering, School of Engineering, Tokyo Institute of Technology. He worked on the design and development of large excavators. Following appointments as manager of the Resource Development System Business in 2007, Director of Product Development and Construction System Business in 2009, and Director of Construction Machinery System Business in 2010, he became an Executive Officer, CTO, and General Manager of the Development and PDI Divisions in 2012. He was appointed Vice President and Executive Officer, CTO, and General Manager of the Development and PDI Divisions in 2014. He took up his current position in April 2015.

transmission, it not only significantly reduces energy losses in power transmission, it also provides more comfortable driving due to the lack of gear changes. It also boosts efficiency further by storing the regenerative energy produced when decelerating in electrical form and reusing it for traction when accelerating. The ZW220HYB-5B developed in 2014 achieves even better fuel consumption, due to being fitted with a hybrid system developed in collaboration with other parts of Hitachi.

Reducing fuel consumption does not just provide benefits to customers in the form of lower lifecycle costs, it is also important for minimizing global warming. To help reduce the load on the environment, we have set a target of halving the fuel consumption of our construction machines by 2020 relative to 2010, and we are working on technical developments on a variety of fronts.

Use of Cloud Technology to Make Mining More Efficient

—Hitachi has identified the mining industry as one of the key focuses of its Social Innovation Business. Please tell us about your activities in this field.

Oono: The challenge at resource development sites is not just to improve the productivity of individual machines but also that of the overall mine operation. Wenco International Mining Systems Ltd., a Canadian subsidiary of Hitachi Construction Machinery Co., Ltd., has incorporated cloud technology of Hitachi, Ltd. into a fleet management system (FMS) for mines to create a cloud-based system that enables more efficient and sophisticated mine operation through the centralized management of the operation of dump trucks, excavators, and other mining machinery, including vehicle dispatch and route optimization and support for performing maintenance appropriately.

A number of companies within Hitachi are currently working together to develop technology for autonomous haulage dump-trucks, including running trials at a test site in Australia. Further improvements in mining operations will be made possible in the future through the integration of autonomous haulage dump-trucks with the FMS.

Our involvement in the mining industry to date has centered around machinery like dump trucks and excavators. But mine operations extend beyond excavation to encompass large-scale activities in a variety of fields, including the transportation of ore and other material, and the power plants at coal mines. This makes it an industry where the wider Hitachi Group has the potential to play a role in a variety of areas. Having identified the mining industry as one of the key focuses of its Social Innovation Business, I believe that, by drawing on Hitachi's areas of expertise that include big data analytics, we will be able to help improve efficiency throughout the mining industry.

Autonomous Haulage System with Potential Applications in Various Fields

—While autonomous haulage systems (AHS) have attracted attention in the automotive sector, I understand you are also working on research and development aimed at its use in mining machinery. What can you tell us about that?

Oono: Further improving the productivity of mining machinery will require measures such as optimal route selection and driving practices to reduce fuel consumption, more efficient operation, interoperation between machines, and the elimination of human error to improve safety. Along with advances in driving support, there is also potential for the use of other technologies such as AHS and robotics.

Current mining machines incorporate a variety of control systems intended to boost their performance. We are honing this technology and working on the development of technologies that support the operation of mining machines with a view toward future AHS, including the adoption of automatic driving technology from the automotive sector, which is a particular focus for Hitachi.

For example, we have already installed peripheral vision support devices that were jointly developed with Clarion Co., Ltd. in our large dump trucks, and in December 2014 we signed a technology licensing arrangement for the "Around View Monitor with moving object detection function" developed by Nissan Motor Co., Ltd. and Clarion. In the future, we intend to continue making improvements to safety by fitting such systems to dump trucks to provide vehicle drivers with better peripheral vision.

In addition to these technologies that augment driver notification functions, we are also proceeding with the commercialization of technologies such as the use of sensors to take realtime measurements, or the use of ICT to help drivers do their jobs. Other work includes the development of technology that combines Hitachi's railway system technology with the Wenco FMS to enable large numbers of mining machines to operate alongside each other safely. Our aim in integrating these diverse technologies is to take on such challenges as AHS and robotics.

Technologies for things like AHS and robotics are already deployed at disaster sites for rescue and recovery work. The dual-arm excavator developed by Hitachi Construction Machinery incorporates techniques from robotics to provide intuitive control of complex operations using its two arms. In addition to use in rescue work by civil defense agencies, the excavator also helped clear rubble following the Great East Japan Earthquake. We also intend to contribute to work on decommissioning the Fukushima Daiichi Nuclear Power Station by accelerating the development of AHS and wireless remote control systems.

A concern with construction work is the shortage of labor and lack of experienced operators. Meanwhile, as infrastructure ages, society is facing the problems of how to reduce the labor requirements and improve the efficiency of inspection and repair work on bridges and other structures. We are putting a lot of effort into the adoption of AHS and robotics in construction and mining machinery, and into the accompanying technologies that assist operation and driving, because of the key role these will play not only in mining but also in the construction, maintenance, and management of social infrastructure.

Cultivation of Ability to Identify Workplace Needs and Offer Solutions

—Please tell us about the development capabilities you have established to contribute to the global market.

Oono: We are working to expand the scope of simulation technologies and boost the speed and efficiency of development in order to establish a reliable supply chain for serving emerging markets and for opening up new markets. Meanwhile, we are also seeking to raise standards and improve quality across the development process by taking steps to review past projects and pass on accumulated knowledge.

Because of the requirement for the functions and specifications of construction machinery to suit the specific circumstances and needs of different regions, we have adopted a development approach that involves designing and building the main modules in Japan and adding "applications" locally for the various functional requirements. Accordingly, along with having Japanese designers become familiar with the local needs of sites around the world so that they can incorporate these into their application designs, we are also building up design techniques suitable for local use by establishing design offices at our overseas operations and training local designers.

Design and development in the global era requires not only satisfying the needs of specific markets but also the ability to suggest how an application that is used for some other purpose in Japan, for example, can be adopted to satisfy particular requirements. On the basis that there is always more than one way (work practice or function, etc.) to achieve any particular objective, fostering the ability to understand the work undertaken at various different workplaces and how they use their machinery, and combining these together, will be major aspects of future staff development.

To become a close and reliable partner anywhere on the earth, as put forward in our 2020 VISION, Hitachi Construction Machinery Co., Ltd. intends to further hone its development and technical capabilities and to work in collaborative creation with other Hitachi companies to continue supplying construction and mining machinery that help build prosperous societies.

Overview

Second Step toward Realizing 2020 VISION

Hidekazu Nakakuro
Manabu Arami

VISION AND MISSION OF HITACHI CONSTRUCTION MACHINERY GROUP

IN 2010, Hitachi Construction Machinery Co., Ltd. formulated its 2020 VISION mid-term management vision that, in looking a decade ahead to 2020, expresses how the company aims to become a "'close and reliable partner' anywhere on the earth with best solutions through Kenkijin Spirit.*1" To achieve this, the company undertook its three-year Go Together 2013 Mid-term Management Plan, which ran from FY2011 to FY2013, and is currently working through its GROW TOGETHER 2016 Mid-term Management Plan from FY2014 to FY2016 (see Fig. 1).

Based on exceptional technology built up over many years, Hitachi Construction Machinery aims to become a global manufacturer of construction machinery with an overwhelming presence by supplying solutions and services that are one step ahead.

*1 Expresses the values and standards of conduct of Hitachi Construction Machinery Group employees in terms of a mindset.

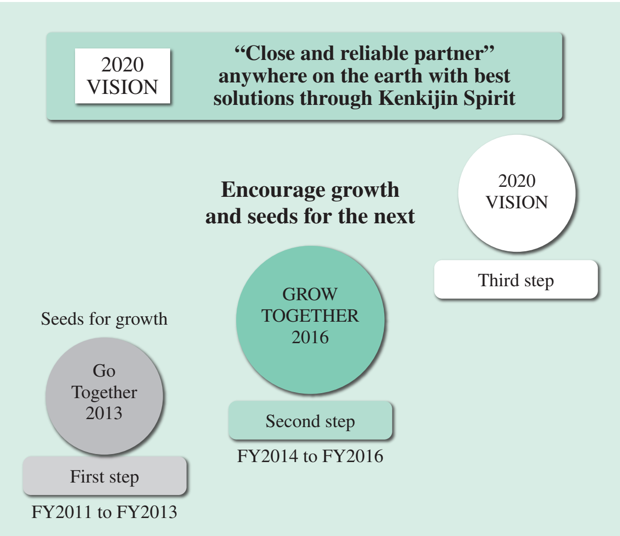


Fig. 1—Toward Realizing 2020 VISION.
GROW TOGETHER 2016, the second step in the 2020 VISION plan formulated to look forward to 2020, is now in progress.

As a manufacturer of construction machinery, Hitachi Construction Machinery's corporate vision is to, "actively develop machinery to make the relationship between people and work more comfortable, advanced, and efficient." Its mission is to make an ongoing contribution to sustainable development by customers and communities by utilizing the diverse products and services that make its vision a reality, to help build and maintain social infrastructure throughout the world.

Hitachi Construction Machinery aims to achieve optimal management throughout the group by continuing the six strategies identified in the previous Go Together 2013 Mid-term Management Plan (research & development, marketing & sales, lifecycle support, mining operation, global production, and global management), and aligning those vectors along the three axes of products, solutions, and regions. While the present business environment makes a major increase in demand for construction machinery look unlikely, the prospect of continued mid- to long-term market growth remains for the construction machinery required to keep up with population increase, urbanization, and further infrastructure provision in emerging economies.

To help build and maintain social infrastructure throughout the world, Hitachi Construction Machinery intends to draw on its networking skills and advanced technical capabilities in hardware and software to continue supplying superior products, services, and solutions that satisfy customers everywhere. Furthermore, to fulfill its social obligations as a business that operates globally, activities at Hitachi Construction Machinery include helping overcome global environmental problems through the latest energy-efficient products, developing advanced technologies that utilize information and communication technology (ICT) to help improve productivity and maintain safety in the workplace, and supplying products that contribute to disaster sites around the world.

As business has become increasingly globalized in recent years, Hitachi Construction Machinery formulated the "Kenkijin Spirit" in 2008 to express the values and standards of conduct of the 20,000 people employed in Japan and elsewhere by the Hitachi Construction Machinery Group so that they could share common values and bring the collective capabilities of the group to bear on achieving the Mid-term Management Plan. This has helped boost its brand value.

The "three Cs" of the Kenkijin Spirit are "Challenge," "Customer," and "Communication."

"Challenge" means learning and adopting a professional attitude to taking on the challenges of research and development, production and procurement, new machine sales, lifecycle support, and other processes to improve technical and marketing capabilities. "Customer" means always thinking about customers' true needs from their standpoint and perspective. "Communication" means trusting in teamwork and taking the initiative in reporting, communicating, and consulting. By sharing these "three Cs" in common, Hitachi Construction Machinery aims to express its identity while growing along with its numerous stakeholders by helping create a sustainable society through the supply of construction machinery.

SECOND STEP TOWARD REALIZING 2020 VISION

In the Go Together 2013 Mid-term Management Plan, the first step toward realizing 2020 VISION, Hitachi Construction Machinery worked on building the foundations of a global supply chain to underpin ongoing growth. This has included commissioning a plant in the Tver Oblast (province) of Russia, a joint-venture plant with Deere & Company in the São Paulo province of Brazil, and the maintenance and expansion of existing production facilities. Along with strengthening its infrastructure for the global supply of spare parts, Hitachi Construction Machinery has also opened the Tsukuba Central Parts Depot to reduce logistics costs. Another area of activity is the provision of overseas sales and service centers in its efforts to raise the level of customer satisfaction around the world (see Fig. 2).

In the GROW TOGETHER 2016 Mid-term Management Plan (the second step), Hitachi Construction Machinery is working to encourage the growth of the seeds it planted in the first step and to sow the seeds of its future.

The company's six key activities are as follows.

(1) Enhancement of development marketing and advanced technology development
(2) Enhancement of sales and marketing
(3) Enhancement of mining[a] operation
(4) Enhancement of parts and service operation
(5) Supply chain management (SCM) reform and enhancement of MONOZUKURI
(6) Enhancement of the entire value chain

(a) Mining
The extraction of minerals out of the ground, or other forms of digging work. Mining is the generic term for work that includes digging ore out of the ground, concentrating it by separating out the valuable material, smelting it to obtain metal, and refining it to increase its purity. "Mining" in the narrow sense of the word refers to the digging process only, with the term "processing" used for sorting ore and subsequent steps.

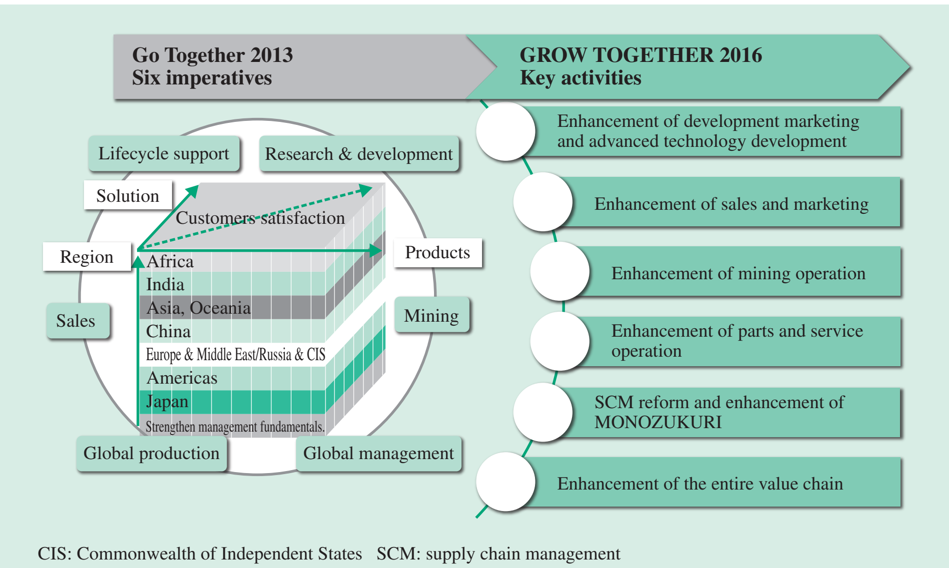


Fig. 2—Key Strategies of GROW TOGETHER 2016.
Continuing on from the six strategies identified in Go Together 2013, GROW TOGETHER 2016 is working on six key activities.

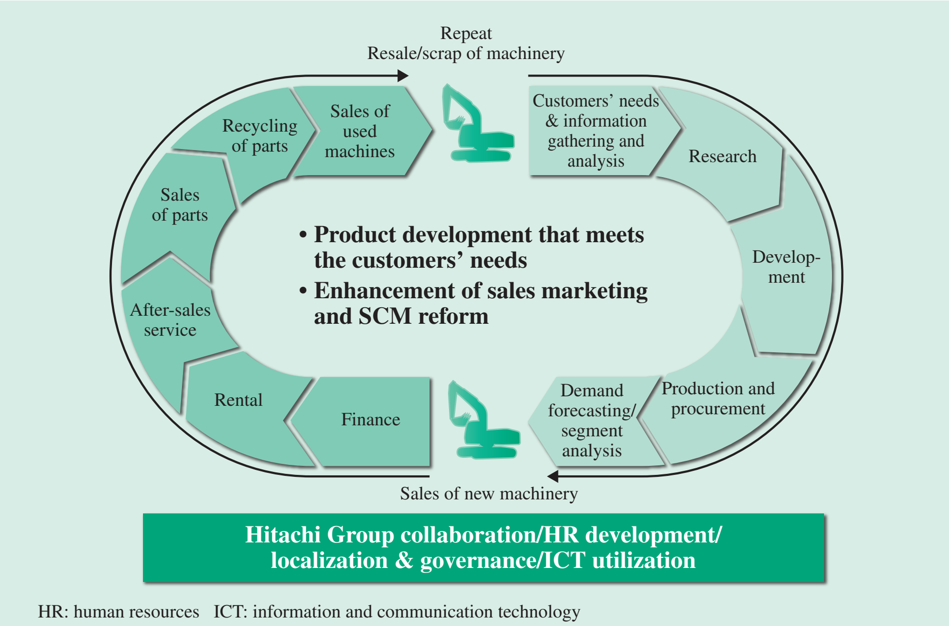


Fig. 3—Strengthening the Entire Value Chain.
This aims to utilize ICT for improving customer satisfaction and increasing sales and profit through the lifecycle of construction machinery.

Hitachi Construction Machinery is seeking to improve profitability further by strengthening its mining-related business and its high-margin lifecycle support business, which it sees as long-term growth drivers.

Also, based on a structure that splits its operations into nine regional businesses [Japan, Asia, Oceania, China, India, Europe and the Middle East, Russia and the Commonwealth of Independent States (CIS), Africa, and the Americas] according to their different market characteristics, Hitachi Construction Machinery is working on company-wide activities that relate to its sales and marketing capabilities and SCM in conjunction with "mother factories" in Japan. It is also improving its ability to generate cash flow by reorganizing itself into a management structure with a high level of operational efficiency that can coordinate production facilities around the world and keep up with the market.

To strengthen its manufacturing capabilities, Hitachi Construction Machinery is shortening the lead times from sales forecasting and ordering to delivery, and raising the level of production process improvement activities and the associated human resource development and energy efficiency management to improve FY2016 unit energy costs[b] by 30% or more compared to FY2010.

To strengthen the entire value chain, Hitachi Construction Machinery is seeking to utilize ICT and operate services that span the entire lifecycle of construction machinery on a global basis. These services include finance, rentals, parts re-manufacturing, and second-hand machine resale. By strengthening the entire value chain, winning the trust of customers and creating a business model that differentiates Hitachi Construction Machinery from its competitors will form the core of future activities (see Fig. 3).

UTILIZATION OF ICT DESIGNED FOR GLOBALIZATION

Advances in mobile devices and the incorporation of advanced functions (collision avoidance, coordinated control, energy efficiency, and so on) into products such as automobiles brought about by the revolution in communications technology and advances in big data analytics mean that growth is anticipated in the market for ICT-based solutions. Labor shortages brought about by the aging of the construction industry workforce and the lack of young people entering the industry are a societal challenge and are driving work on ways of using ICT to improve labor productivity, such as information-oriented construction[c].

Meanwhile Hitachi Construction Machinery's advantage is that it has built a digital platform that

(b) Unit energy costs
The amount of electric power, heat, or other form of energy required to produce a fixed amount of product. Unit energy cost is used as an indicator of how efficient production is in terms of energy, and of how energy efficiency is progressing.

(c) Information-oriented construction
A concept relating to the use of ICT to perform construction work with a high level of efficiency, precision, and quality, and the systems required to achieve this. In addition to adopting more advanced construction practices, it is a way of improving the productivity and ensuring the quality of an entire construction project by utilizing the electronic information obtained from work in other processes.

combines products and services that exploit its know-how in strengthening services and support and its synergies with other Hitachi businesses, with approximately 190,000 of its machines operating around the world fitted with communication units that collect data on machine position and operation. This enables Hitachi Construction Machinery to become a trusted brand and differentiate itself from its competitors by delivering value over and above customer expectations.

Among the machines made by Hitachi Construction Machinery are hybrid excavators and industry-first (based on Hitachi Construction Machinery research) hybrid wheel loaders[d]. It is also working to make its machines smarter, including by adopting the "Around View Monitor with moving object detection function[e]" technology from Nissan Motor Co., Ltd. and Clarion Co., Ltd. to provide operators with better visibility and safety.

Other work includes the development of the autonomous haulage dump-trucks, which integrate machinery and systems, and the global deployment of the ConSite*2 service (described below) that utilizes operational data from machines.

(d) Hybrid wheel loaders
Wheeled tractor-loaders used to transport earth or gravel at construction sites or mines, or to load it onto dump trucks. Also used in agriculture or for clearing snow. While most wheel loaders are powered by a diesel engine, hybrid models use a diesel engine to drive a generator that supplies power to the electric motors that drive the vehicle.

(e) Around View Monitor with moving object detection function
In addition to displaying images from four cameras mounted on the front, back and sides of the vehicle, this system also analyzes the image signals to detect nearby moving objects in realtime. If the cameras detect a moving object while the vehicle is stationary, or starting to move forward or backward, the system displays this on the screen and gives the driver an audible warning.

*2 ConSite is a trademark of Hitachi Construction Machinery Co., Ltd.

HITACHI'S INVOLVEMENT IN MINING MARKETS IN THEIR ROLE AS GROWTH DRIVERS

For the mining industry, Hitachi Construction Machinery has developed a highly reliable ultra-large hydraulic excavators and dump trucks driven by large, alternating current (AC) electric motors that utilize bullet train technology developed by Hitachi, Ltd. These machines are used in mines around the world.

Given the difficult business environment, achieving more efficient mine management to reduce costs is an even greater challenge for resource companies than it has been in the past. Wenco International Mining Systems Ltd., a Canadian information systems company, has completed testing and evaluation of a system that uses advanced cloud technologies of Hitachi, Ltd. to consolidate information about mine management in the cloud and provide centralized management, and has now started commercializing the product. The system aims to make mining operation more efficient by using the centralized analysis of operational data from mining equipment to support the routing and dispatching of dump trucks and help perform maintenance appropriately (see Fig. 4).

In the future, Hitachi Construction Machinery aims to build a win-win relationship with the customers of its mining equipment by incorporating electronics and automotive safety control systems, two of Hitachi's strengths, as well as by enhancing integration with systems to achieve overwhelming improvements in performance and reliability and to minimize lifecycle costs that are measured by unit of material excavated.

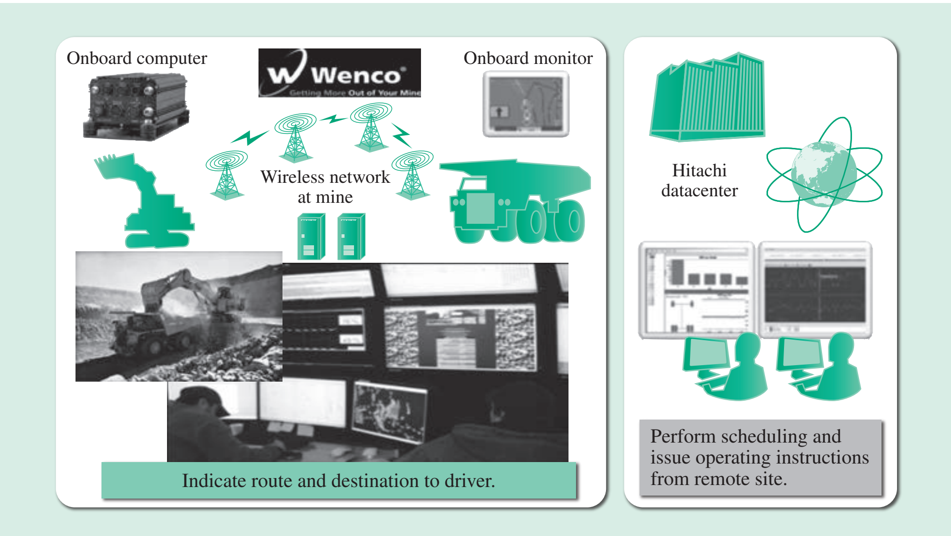


Fig. 4—Strengthening Solutions with Other Hitachi Companies.
Wenco uses advanced cloud technology from Hitachi, Ltd. to boost the efficiency of mine operations, and is working on commercializing a cloud-based mine management system.

STRATEGIES FOR DEVELOPING PRODUCTS THAT MATCH CUSTOMER NEEDS

In accordance with rising demands for energy efficiency performance and safety, as well as the basic strengths of reliability and durability, product development at Hitachi Construction Machinery Group fuses its strengths in the core technologies of construction machinery with the electronics, electric drive, and ICT capabilities of the wider Hitachi Group. The current era is one in which the strengths that come from being part of this wider corporate group will prove to be major advantages. Specific examples are to be found in the articles in this issue entitled, “ZAXIS-6[*3] Series Hydraulic Excavators Equipped with Latest Environmental Technology,” “EH-3 Series Dump Trucks Enhanced by Comprehensive Capabilities of Hitachi,” and “Hybrid Wheel Loaders Incorporating Power Electronics.”

Hitachi Construction Machinery is also drawing on the strength in the development of application-specific products that it has built up in Japan. By dealing with front-running customers over many years, Hitachi Construction Machinery has developed application-specific products that dramatically improve work efficiency in fields such as building demolition, vehicle dismantling, forestry, and port cargo handling. With the aim of helping to overcome the management challenges of how to reduce operating costs and improve safety, Hitachi Construction Machinery is seeking to improve its technical development capabilities by making ongoing improvements to things like ease of operation, vibration, and the fuel efficiency of work (see Fig. 5).

STRATEGIES FOR UTILIZING LIFECYCLE SUPPORT TO INCREASE CUSTOMER SATISFACTION

The sales company, Hitachi Construction Machinery Japan Co., Ltd., has a network of facilities located throughout Japan that serves as the foundation of its business. In Japan, Hitachi Construction Machinery has boosted customer satisfaction and increased sales and profits by operating its Rental (R) - Sales (S) - Service (S) business that utilizes this network. Unlike Japan, however, the requirement in overseas markets is to cover a wide range of different businesses, and this makes it impractical to operate a large number of facilities. This means that ICT is a key factor in business competitiveness.

Drawing on know-how in after-sales services in Japan, Hitachi Construction Machinery has been involved since 2004 in its Global e-Service, which consolidates about 40 different service programs and is used in 20 different languages in 185 countries or regions. The ConSite operational information service for new machinery was developed from this Global e-Service. The service launched throughout the world in April 2014 and is already supplying services to more than 10,000 machines.

Hitachi Construction Machinery is using ConSite not only to supply customers with information on machine operation, but also to expand its spare parts business (thereby increasing profit) by providing appropriate follow-up on maintenance and other services.

The major benefit of ConSite is the value it provides to customers by preventing machines from being out of service. If a machine detects an urgent problem with the potential to take it out of service, it sends an emergency report to the operator or owner so that they can take action before a failure occurs. Similarly, if a machine does go out of service, it can be repaired quickly. Use of ConSite information can also

Fig. 5—Application-specific Products Used at Various Different Sites.
Drawing on its capabilities for the development of application-specific products built up over many years, Hitachi Construction Machinery is helping reduce operating costs and improve safety for a large number of customers at a diverse variety of workplaces.

*3 ZAXIS is a trademark of Hitachi Construction Machinery Co., Ltd.

help dealers with wide geographical coverage increase meaningful contacts with customers.

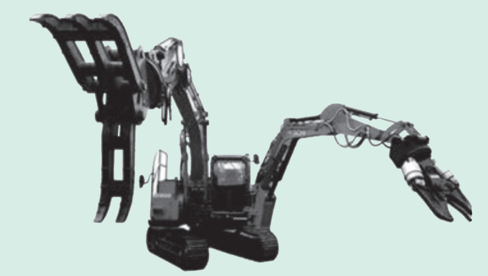
Furthermore, using ConSite to identify warning signs of machine faults or other problems and performing maintenance accordingly can extend machine life and increase resale value. This leads to lower lifecycle costs for customers.

CSV INITIATIVES

If companies are to grow sustainably, it is essential that they pursue their growth strategy and manage their corporate social responsibility (CSR) in a unified manner. Since establishing a CSR Promotion Department in 2005, CSR at Hitachi Construction Machinery has passed through the "initial" and "growing" phases and is now entering a "deepening" phase.

The primary prerequisite for sustainable growth is the global deployment of products and services that satisfy customer needs, generating sales and profits by achieving customer satisfaction. Hitachi Construction Machinery undertakes its corporate activities with a mission of growing in tandem with its numerous stakeholders, including paying out its revenue as taxation, shareholder dividends, and employee remuneration, and investing in things like the research and development of advanced products or the expansion of sales and service facilities.

This involves treating the resolution of societal issues as an opportunity for business. This does not just mean seeking to address global-scale societal challenges by achieving energy efficiency and zero emissions at its production facilities, for example, it also includes taking an active role in the development of low-carbon machinery such as hybrid or other battery-powered machinery that minimizes carbon dioxide (CO_2) emissions. Hitachi Construction Machinery also supports the way its machines are used by customers to build towns and earthworks that are compatible with the environment. These are called "CSV[f] activities" that aim for benefits that are shared with customers and other stakeholders.



CSR: corporate social responsibility

Fig. 6—Dual-arm Excavator Incorporating Robotics Technology.
The two excavator arms improve work efficiency and enhance safety through the mechanization of manual labor. The excavators are also utilized for CSR activities through their use in disaster recovery work.

(f) CSV
An abbreviation of "creating shared value," the concept of CSV was proposed by Professor Michael E. Porter of Harvard Business School as an alternative to CSR. It is the idea that companies can contribute to creating a sustainable society by simultaneously pursuing economic value (profit) and solving societal challenges with reference to the principles of CSR.

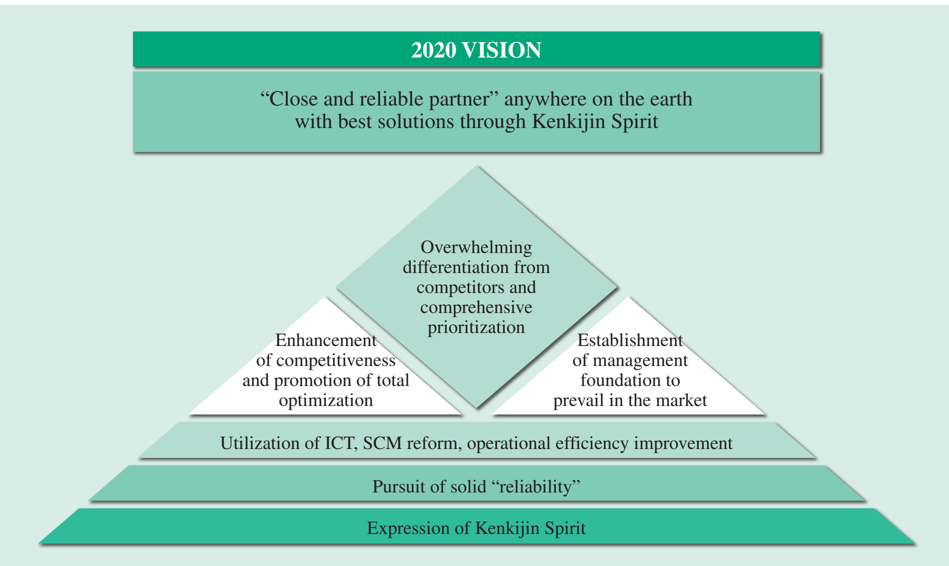


Fig. 7—Core Strategies of Hitachi Construction Machinery.
Hitachi Construction Machinery is seeking to be a close and reliable partner to customers around the world through the pursuit of "reliability and differentiation."

While the first generation of hybrid machines delivered a 20% reduction in fuel consumption compared to previous models, savings on the current second-generation models are 30%, with a halving of fuel consumption being the objective for the future. Hitachi Construction Machinery has successfully trialed operation on 100% algae biofuel to help reduce CO_2 emissions and intends to utilize the knowledge obtained from research into increasingly diverse fuels in even more impressive product developments in the future. Being actively involved in environmental measures includes being one of the first companies in the construction machinery industry to apply carbon offset mechanisms to forestry machinery.

The dual-arm excavators used at disaster sites are contributing to CSR activities as well as research into robotics by improving safety through the mechanization of manual labor, improving efficiency through use of the versatile second excavator arm, and saving space by enabling one machine to do the work of two (see Fig. 6).

BECOMING A CLOSE AND RELIABLE PARTNER

As it steadfastly implements its GROW TOGETHER 2016 Mid-term Management Plan, the second step toward realizing its 2020 VISION, the Hitachi Construction Machinery Group is pursuing “reliability and differentiation” (see Fig. 7). In doing so, it is seeking to be a close and reliable partner to customers around the world.

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Featured Articles

Global Deployment of Mining Solution Business Powered by ICT

Yoshinori Furuno
Phil Walshe
David Noble
Mutsumi Kitai

OVERVIEW: In recent years, the global operations of the mining industry have been directed toward achieving greater efficiency through use of rapidly advancing ICT. Vehicle dispatch systems have evolved from systems that merely guide dump trucks to their destinations into FMSs that provide integrated operational support encompassing blasting plans, managing the quality of the transported material, improving safety, and managing the condition of fleet vehicles. Accompanying this change has been a dramatic increase in the volume of data being handled at mine sites. In the future, the key requirement will be to draw on synergies with other parts of Hitachi to provide systems that can collect this data efficiently and accurately and contribute to the optimization of mining operations.

INTRODUCTION

THE environment in which the mining industry operates became even more difficult with the advent of the global economic recession set off by a crash in sub-prime loans in the USA. Despite the continuation of vigorous demand in emerging economies, the delayed recovery of the European economy and the slowing in China's rate of growth indicate an oversupply of iron ore and other minerals, with the slump in commodity prices continuing. The price of the coking coal used in the smelting of iron ore has also been affected by these trends. Meanwhile, the price of gold has risen steadily over the last 10 years or so, and with the associated increase in production volumes being accompanied by rising costs, the recent sudden fall in the gold price has been a major blow to mining operations. Given this background, more so than increasing production volumes, mining companies have now come to see making production safer and more efficient as being their major challenges, regardless of the type of mineral involved.

In this environment, Hitachi Construction Machinery Co., Ltd. has been making its machinery more intelligent, including through the use of electronics in mining and digging machinery to improve operating performance, and through the release of a series of mining dump trucks with alternating current (AC) drive that incorporate motors and inverters from Hitachi, Ltd. To supply mines around the world with not only mining machinery but also the fleet management systems (FMSs) used to manage their operation, Hitachi Construction Machinery acquired Wenco International Mining Systems Ltd. in July 2009 with the aim of providing support for more efficient mining operations. Wenco has its headquarters in western Canada.

Since its acquisition, Wenco has progressively increased its market share through measures that include working with Hitachi Construction Machinery sales offices throughout the world to offer its services as a package together with mining machinery. Wenco systems are currently in use at 70 mines around the world. Amid growing awareness in the mining industry of cost and safety, Wenco not only develops its own products but is also taking advantage of synergies with other Hitachi companies including its parent, Hitachi Construction Machinery, to build a solution business based on information and communication technology (ICT).

This article looks back at the establishment and history of Wenco and describes the background and features of past products together with the current situation and future outlook for solution businesses based on IT.

EVOLUTION FROM DISPATCH SYSTEM TO FMS

The core Wenco system is a dispatch system with a primary objective of ensuring that the dump trucks at a mine site operate efficiently between the various loading sites and the unloading site or crushing and

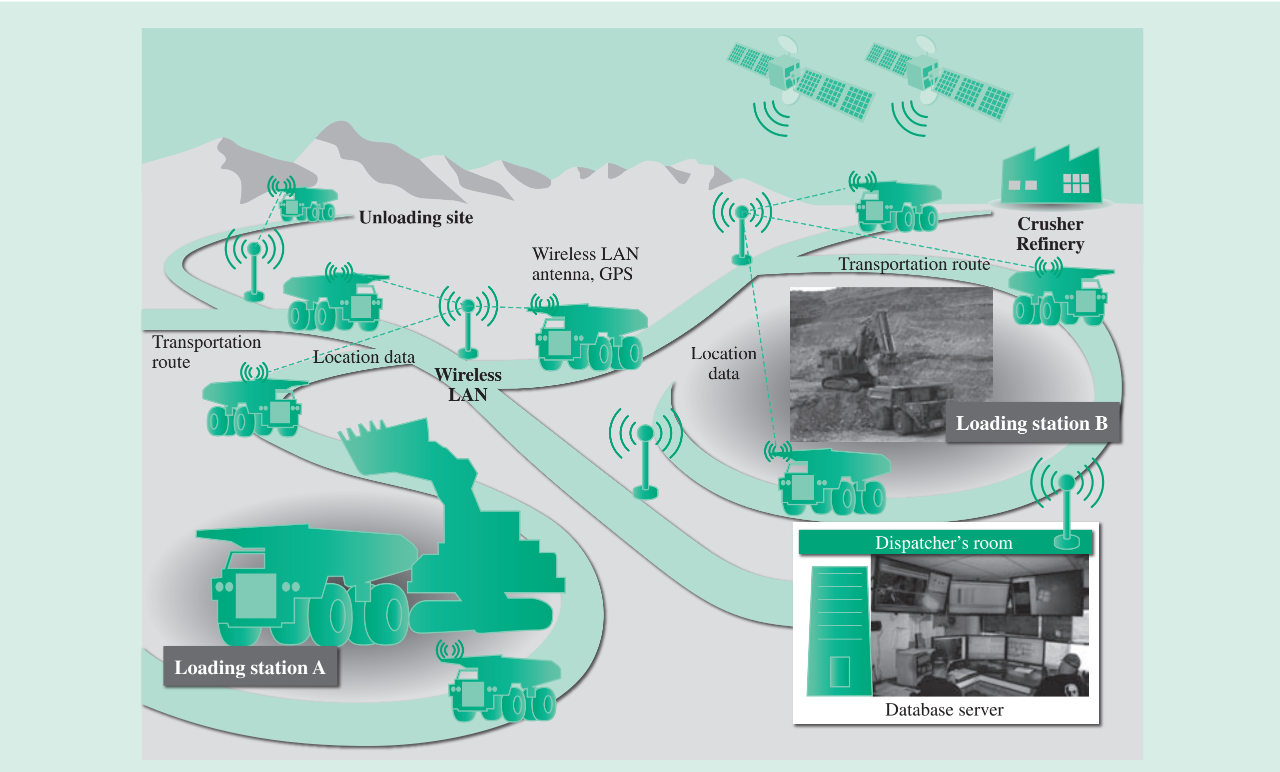

Fig. 1—Overview of FMS.
The figure shows an overview of the FMS. Dispatchers set production volume and other KPI targets in the system and issue instructions to dump trucks and loaders based on these. The system maintains the quality of ore being supplied to the crushing, refining, and other plants.

refining plant. With the performance of onboard computers having improved in recent years along with the volume of data able to be carried by wireless local-area networks (LANs), Wenco has added a variety of new functions to this system, transforming it into a mine FMS (see Fig. 1).

The following sections describe how the Wenco system has evolved from its origins to become the product it now is.

History of Wenco

Wenco's history dates back to the 1980s when it started out as part of the engineering division of Wester Mining (Kaiser Resources), a mining company that primarily operated coal mines in western Canada. One of the mining engineers working there at the time was Phil Walshe, now the President and CEO of Wenco. In 1985, the group developed a system to optimize vehicle dispatching at the company's mines. The system was made up of comparatively inexpensive personal computers (PCs) and wireless communications, and ran on a Microsoft* operating system (OS). The group was subsequently spun off, initially as Wester Engineering Company, which was later shortened to Wenco and the company was renamed to Wenco International Mining Systems[1] as it is now known. The dispatch system that formed the prototype of the current system was called the production monitoring and control system (PMCS) and was created based on the actual requirements of mine operations. An approach to development that pays constant attention to the requirements of the mines has remained a feature of the company since its inception.

In the 1990s, the first vehicle dispatch system to use the global positioning system (GPS) to obtain machine locations was installed at a large gold mine in Western Australia. Subsequently, they added an SQL Server* database in 2000 for easier data extraction. The system uses the database for storing and managing data, and, like the OS, SQL Server is a Microsoft product. This made it comparatively easy for mine operations staff to access productivity-related data stored in the vehicle dispatch system and process it further or use it for reporting on other Microsoft products.

Product Evolution

In response to customer requests, the system was expanded beyond vehicle dispatch to also include managing the quality of material loaded onto dump trucks at loading sites. In 2004 they released a High Precision GPS Guidance System that checks the quality of the ore to be transported to its destination as the excavator operator loads it into a vehicle by using high-precision GPS to display each loader's excavation location on a map that shows the grade of ore in the ground and is pre-loaded into the vehicle's onboard computer (see Fig. 2). This system helps minimize variations in quality by checking the accuracy of ore composition at the loading stage as it is dumped into the crushing or refining equipment. It also improves the accuracy of recorded information by automatically sending information about the ore being loaded onto a dump truck, including its quantity, to the database server in the dispatchers' room. This ore information, which previously relied on data entered by the loader driver, is now determined from the loader's excavation position, obtained using high-precision GPS.

At this time, the number of sensors fitted on mining machinery to provide status indications was increasing significantly, leading to demand for using the outputs of these sensors to monitor machine status and provide a basis for maintenance planning. In response, Wenco developed Asset Health Management System, a new function for the realtime monitoring, display, and recording of alarm and sensor data from machines at the office. The function was first sold for Hitachi Construction Machinery mining machinery with support for machines from other vendors added as needed.

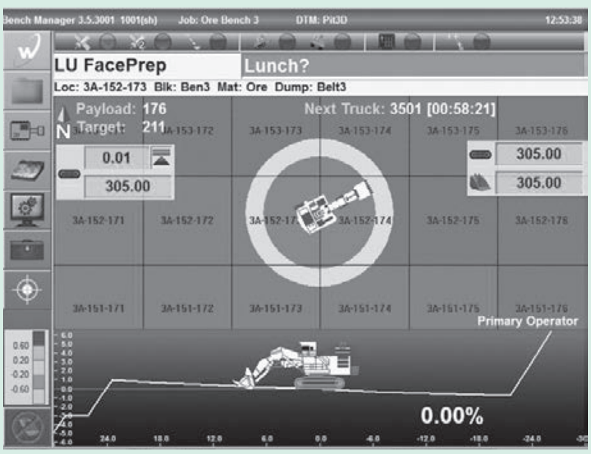

Fig. 2—Directions Using High Precision GPS Guidance System.
The operator determines the grade of the ore being loaded into the dump truck while viewing the ore-specific blocks around the loader.

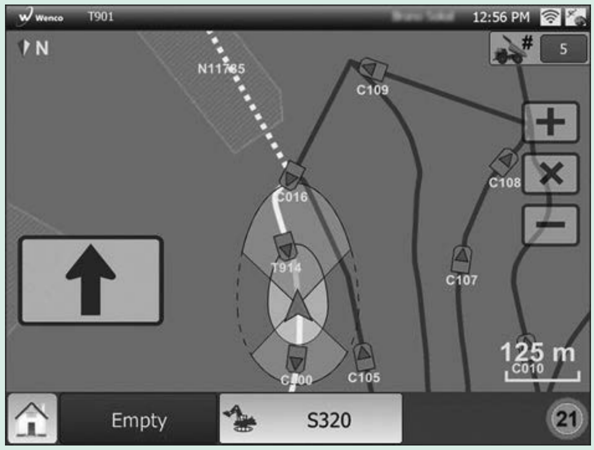

Fig. 3—Navigation (Tune-by-Turn Vehicle Guidance System/ Fleet Awareness).
The system encourages drivers to reach their destination on time by displaying the route on a map. It also reliably identifies any approaching machines or vehicles in the vicinity.

To support safety, Wenco also developed the Tune-by-Turn Vehicle Guidance System, which provides map-based directions to guide dump trucks or other vehicles to their destinations safely and efficiently despite routes changing on a daily basis (unlike a typical urban situation). Sales and support of Tune-by-Turn Vehicle Guidance System commenced in 2014 (see Fig. 3).

Wenco also developed a web-based dashboard function, also released in 2014. In an environment in which data such as positions or haulage quantity per track are continually changing, this enables vehicle dispatchers and other staff involved in mine operations to perform comprehensive realtime monitoring of data in a variety of forms, not just on a dedicated dispatch computer located in the dispatchers' room.

COLLABORATION WITH HITACHI GROUP

Vehicle Safety Support

As further functions are added to its FMS, Wenco is seeking to collaborate with other Hitachi companies through an active policy of incorporating Hitachi technology while also remaining attentive to what customers have to say. Wenco's vision is to strive to undertake system development in a way that integrates the "machines" that operate at a mine, the

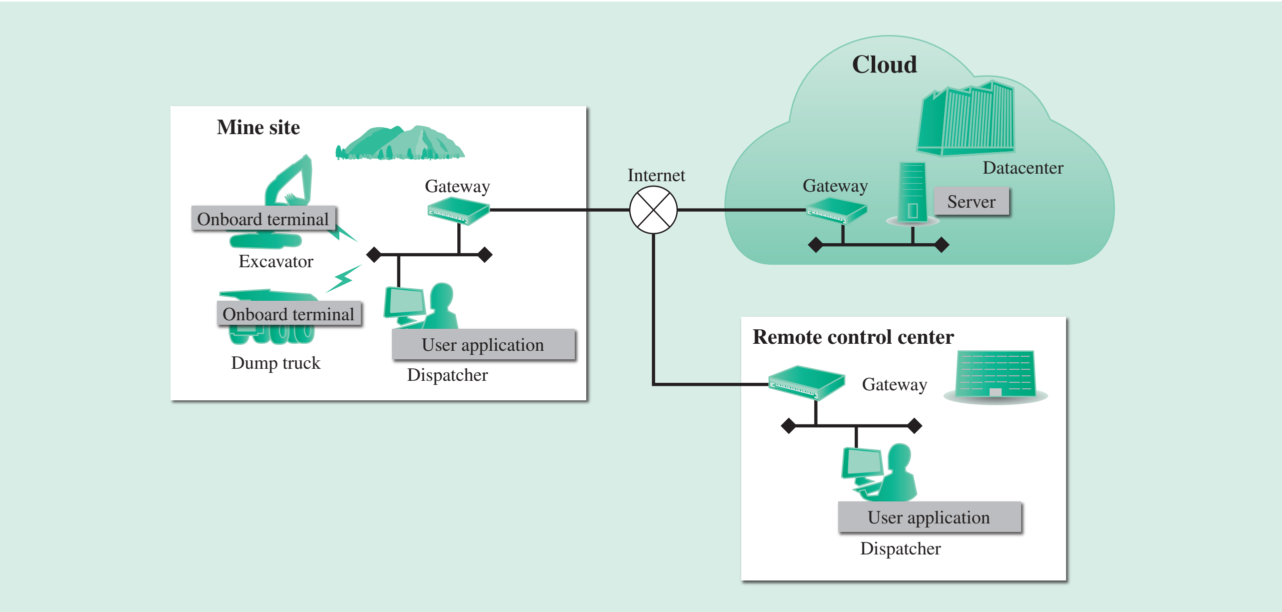

Fig. 4—Concept for Remote Control Center Using Cloud.
This runs the FMS in the cloud to control the FMS of the mine site remotely.

"ICT" that represents information and communication technologies, and the "humans" (people) who use both of these. As part of this, and to ensure that machines and people can work more safely at mine sites, Wenco is extending its Tune-by-Turn Vehicle Guidance System using technology for monitoring the surrounding area based on vehicle-to-vehicle communication technology built up by the Research & Development Group at Hitachi, Ltd. through its involvement in the automotive industry. In addition to wireless links via the mine office where the dispatchers' room is housed, the technology is able to establish direct communications between nearby vehicles or other machines and to use this to determine each one's position and direction of movement more reliably. It can also implement systems that reduce false reports to a bare minimum through the use of logic that can utilize maps and other information for the accurate prediction of potential collisions in various different situations. This technology is scheduled to go on sale during FY2015.

With the aim of combining its FMS with driverless dump trucks, Wenco has been developing its autonomous haulage system for driverless dump truck operation in collaboration with Hitachi Construction Machinery since 2012. It also plans to spin off functions and other technology developed for this purpose and progressively deploy it on current Hitachi Construction Machinery machines to provide functions for improving things like safety and productivity.

Use of Cloud Technology

Along with the integration of machines and ICT, work on research and development of systems that combine ICT with people, who supervise its operations, has been in progress with the Information & Telecommunication Systems Company of Hitachi, Ltd. since 2012. With a view to handling operations at distant mine sites from a city-based remote control center, Hitachi is working with mining companies on the west coast of Canada to trial the cloud-based operation of Wenco's FMS (see Fig. 4). This trial has demonstrated that the use of Hitachi, Ltd. wide-area network (WAN) accelerator technology can dramatically improve operation response times, which are a factor in ease of operation and, by clarifying operational issues, has taken a major step forward toward commercialization(2).

FUTURE DEPLOYMENT AS MINE OPTIMIZATION SYSTEM

The system design put together by a group of engineers at a division of a mining company more than 30 years ago was more than just a simple vehicle dispatch system. Also present at the time was the idea of a system that performs optimization across all aspects of mine operations, an idea that has existed since that time. While the operating costs of crushing, refining, and other plants used in the downstream production processes at mine sites like that shown in Fig. 1 tend to be much higher than those for the excavation, loading, and transportation processes, these costs are strongly influenced by the purity (quality) and quantity of the ore supplied to the plants by the upstream processes. Even when the system was first being developed, they envisaged performing optimization through a system designed for accurate, realtime detection of these parameters that could provide them as feed-forward inputs to the downstream processes.

One example is the use of chemical solvents to extract the metal at gold and copper mines, with the quantity of solvent being determined based on the purity (quality) of the ore that is fed into the plant. If the quantity of chemical solvent is too low for the purity of the ore, not all of the gold or copper will be extracted, resulting in a large loss. In the opposite case, using too much of the expensive solvent is wasteful. Similarly, if the quantity of feedstock supplied to the plant is less than its processing capacity, it will adversely affect the plant's productivity. The initial concept for the optimization system was to dynamically synchronize the large variations in the upstream and downstream processes.

The main forms of radio communications used when the system was first envisaged were ultra-high frequency (UHF) and very-high frequency (VHF), neither of which was suited to handling large amounts of data in realtime. Furthermore, as data on the position of loaders, dump trucks, and other vehicles was limited, with few sensors for monitoring machine status, the optimization system was not able to be implemented as intended.

In recent years, wireless technologies such as IEEE802.11x have emerged that are able to handle large volumes of data at high speed. There have also been notable advances in technology such as more precise GPS for better positioning accuracy, and machines have started to incorporate a large number of sensors for monitoring their status and output (how many tons of material have been transported). Along with this, Wenco developed High Precision GPS Guidance System (described above) for monitoring load quality, and subsequently the Asset Health Management System for monitoring machines to prevent sudden faults. It also developed Tune-by-Turn Vehicle Guidance System to enable mines to operate safely by maintaining an accurate view of mine environments, which change dynamically on a daily basis. Wenco has also collaborated with Hitachi, Ltd. on testing cloud-based systems that extend beyond on-site communications to manage mines remotely. Through this work, it is moving a step at a time toward a mine optimization system.

Next, tools are needed that can analyze large amounts of data from multiple perspectives to synchronize the upstream and downstream processes by analyzing the constantly changing data associated with mine operation. In 2015, Wenco started developing an analysis system based on business intelligence (BI) tools in collaboration with the Information & Telecommunication Systems Company of Hitachi, Ltd. (see Fig. 5). These BI tools will be adapted for mining companies that increasingly

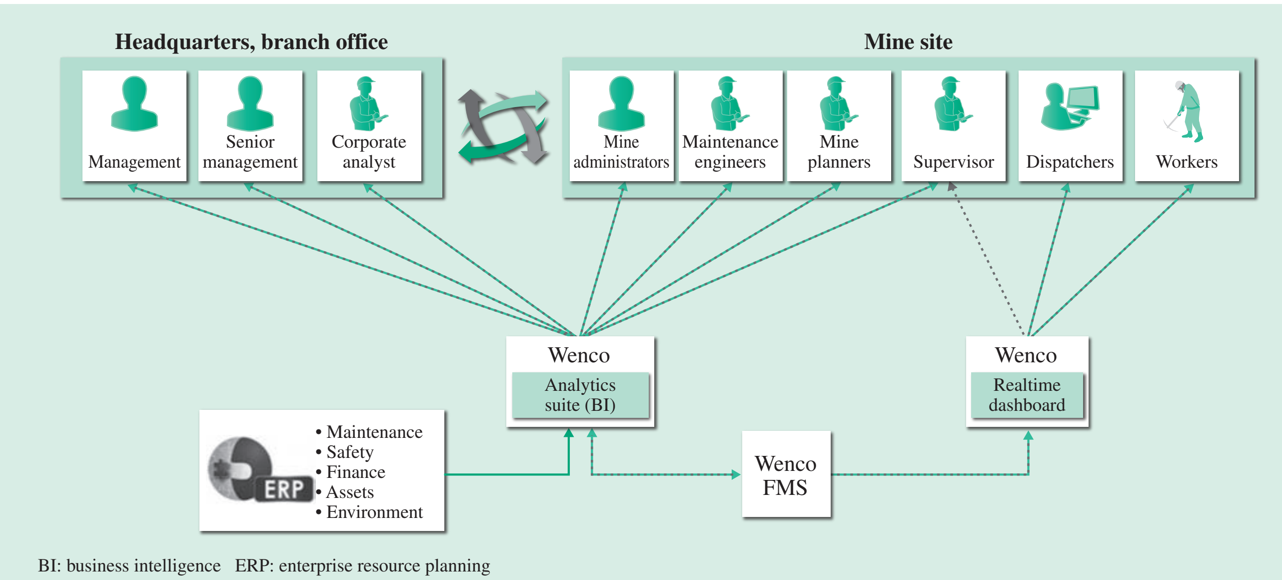

Fig. 5—Overview of BI Tools.
Production information output by the Wenco FMS can be analyzed not only by dispatchers, but also by a variety of other stakeholders.

operate as oligopolies, with a view to shifting them to the cloud for monitoring the status of production processes across a number of mine sites, instead of just one site at a time.

Meanwhile, Hitachi is utilizing its information technology (IT), operation technology, mining machinery technology, and consulting capabilities and experience in a wide variety of industries to improve productivity and perform other optimizations all the way from excavation to the railway and port, and undertaking mine operation support from equipment to operation, maintenance, and management support as part of its Social Innovation Business(3). Wenco intends to take part in this work in ways that include solution development and the use of equipment information in its role at the core of the mining sector.

CONCLUSIONS

Having started in the 1980s as a vehicle dispatch system, the Wenco FMS has now become vital to the optimization of mine operations. The challenge for the future is to provide total support for reliable production by minimizing the factors that cause production to vary at mines that have complex ore bodies and that tend to change more dynamically than other types of industrial plants. The next major step will be to integrate FMSs and other types of ICT into machines to make them smarter and to implement control systems that support "humans" (people) in terms of production, safety, and other considerations. Given the demand for optimization of the entire mining process from pit to port, Hitachi aims to deploy its comprehensive capabilities and go beyond its organizational structure as a mining machinery vendor to become a broad-based solutions company.

REFERENCES

(1) Wenco International Mining Systems Ltd., http://www.wencomine.com

(2) K. Sodeyama et al., "Cloud-based Fleet Management System Proof of Concept," Hitachi Review **64**, pp. 29–34 (Feb. 2015).

(3) Y. Kuba et al., "IT Platform Solutions for the Social Innovation Business," Hitachi Review **64**, pp. 69–73 (Feb. 2015).

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Featured Articles

ConSite Next-generation Service Solution Utilizing ICT

Yoshiya Hamamachi
Koji Seki
Satoshi Inose
Kunio Seki

OVERVIEW: There has been a shift in customer concerns over recent years toward reducing lifecycle costs and improving machine availability. Hitachi Construction Machinery Co., Ltd. uses ConSite, a next-generation service solution that utilizes ICT, to deliver a consistent level of high-quality service to customers throughout the world. The company first launched its ConSite Data Report Service for the automatic worldwide distribution of operational information about hydraulic excavators and wheel loaders in Japan in October 2013, with further deployment to other countries from April 2014. As of the end of February 2015, the ConSite service was available for 99,750 machines. The number of machines actually covered by contracts has surpassed the target of 5% to reach 15% of this total by the end of February 2015. Hitachi Construction Machinery intends to expand the range of services it offers in the future.*

INTRODUCTION

WITH the construction machinery industry facing growing demands from society, clean diesel has become a requirement for participation in public works. The stage 1 standards under the regulatory system for construction machinery emissions were introduced for projects undertaken under the direction of the Japanese Ministry of Land, Infrastructure, Transport and Tourism in 1991, the stage 2 standards in 2003, and the stage 3 standards in 2006.

Furthermore, regardless of industry, a high priority has been placed on reducing fuel costs amid the price rises and violent fluctuations in fuel prices over recent years. Because construction machinery is used for heavy work, fuel costs naturally have a significant impact on the total lifecycle cost of machines, and there is a high degree of interest in measures for reducing fuel costs as well as in information on the subject, especially for major customers with large fleets. In particular, fuel-efficient operating practices that utilize information and communication technology (ICT) have become widely recognized as an issue for customers, primarily in developed economies. While construction machinery manufacturers have been adopting innovative measures and making data available on special-purpose websites, not all customers are able to make good use of this information because its use for fixed-point observations requires them to have information technology (IT) skills and to make an effort to collect information.

Meanwhile, advanced skills are now required to repair faults in the control systems of construction machines that involve a complex combination of electronic, hydraulic, and mechanical control to reduce fuel consumption and emissions. Customers concerned about being able to get a quick response when an unexpected fault takes a machine out of service have high expectations for the use of ICT to make available information on operating conditions and enhancements to service infrastructure.

In response to these background factors, Hitachi Construction Machinery has started offering customers its ConSite after-sales service program for construction machines that utilizes ICT. Fig. 1 shows an overview of the service. After undertaking the appropriate procedures with their distributor, customers are able to receive comprehensive monthly reports by e-mail without any effort required on their part, and without needing to log in to a website each time or search for information, etc.

FEATURES OF CONSITE

ConSite is a package from which customers can choose services as required. One option, the Data Report Service, was introduced in Japan in October 2013, with test operation and service delivery commencing globally in 2014, except in North and South America where after-sales service is handled

* ConSite is a trademark of Hitachi Construction Machinery Co., Ltd.

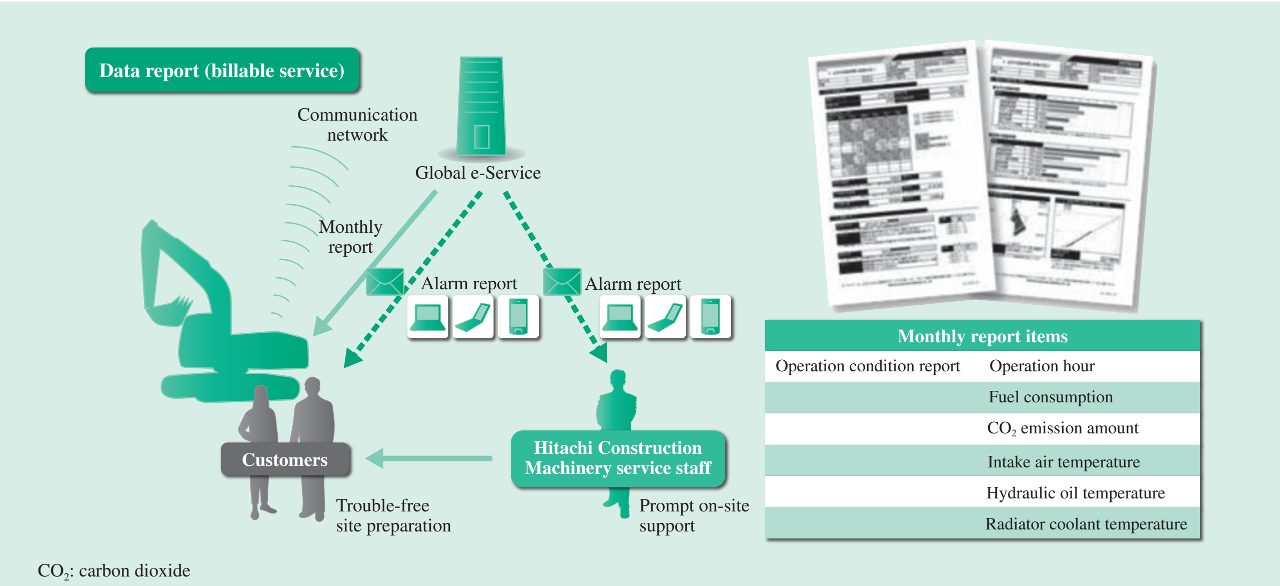

Fig. 1—Overview of ConSite Data Report Service.
The service is a support system that utilizes the sensing functions on machines to provide customers and distributors with timely machine-specific information about their operation and faults.

by Hitachi's partner, John Deere (Deere & Company) of the USA.

The data report service consists of a monthly report service and alarm report service. The features of these are described below.

Monthly Report Service

The monthly report service automatically collects data on machine operation over the previous month and sends it to the customer by e-mail. The service is available in 29 different languages and provides a set of reports that include both summary reports listing information for multiple machines and detailed reports showing operational data for individual machines. Fig. 2 shows the title pages of the monthly reports.

The service makes it easy for customers to obtain information on machine operation in the form of calendar-format operational data, total operating hours, fuel consumption, average fuel consumption, and comparisons with previous months, and also an ECO Operation Report with indices that show trends in energy-efficient operation calculated using proprietary averaging logic. The service also provides an objective assessment of machinery status through comparisons against the average values for other machines of the same model in nearby regions. Because the reports clearly show how the operational efficiency of construction machinery, which tends to vary from operator to operator, differs from previous months, they are readily able to help with workplace awareness by providing motivation for reducing fuel consumption.

Using measures such as frequently turning off the engine when the machine is idle can significantly reduce fuel consumption as well as the proportion of non-operating time relative to the average (see Fig. 3).

The service is also useful for machine maintenance management, having been designed to facilitate maintenance planning based on information about operation and alarms generated over a one-month period.

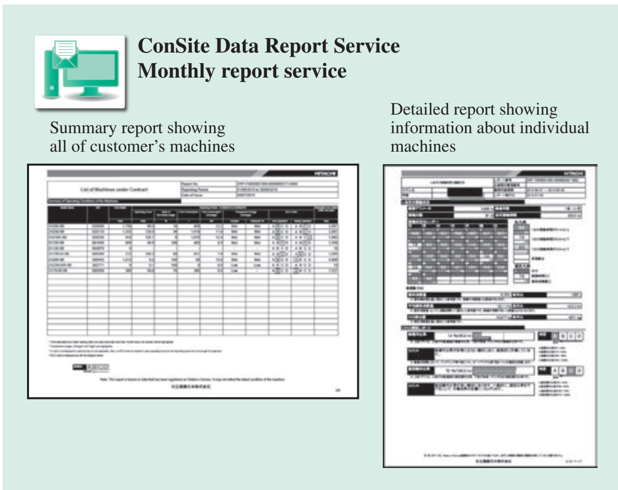

Fig. 2—Title Pages of Monthly Reports.
The service provides both summary reports that give an overview of the operation of all the fleet owner's machines, and detailed reports that show information about individual machines.

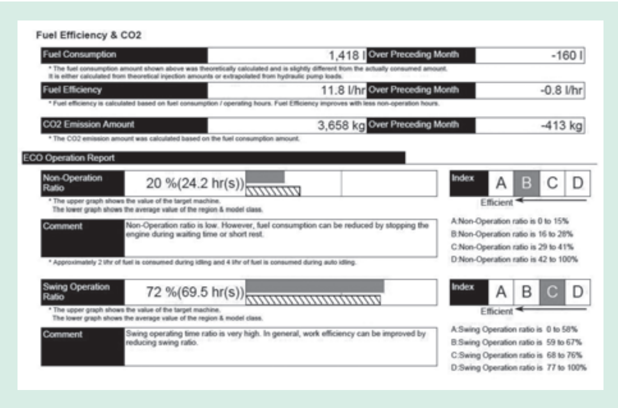

Fig. 3—Fuel Consumption and ECO Operation Report.
Factors such as fuel consumption (a top priority for customers) and operation over the month are ranked (A, B, C, or D) based on their respective operation ratios.

Alarm Report Service

The alarm report service sends notifications to specified e-mail addresses, such as the customer's office or smartphone, when a problem occurs that requires urgent attention and has the potential to take a machine out of service. The aims of the service include shortening machine downtime by enabling staff to keep up with what is happening on the ground, even when away from the site.

Ahead of its competitors, Hitachi Construction Machinery has been providing a similar service since 2000 that has since been copied by others. What makes this service different is its "intelligence filter" function, which uses data science to restrict the information to only that of relevance to the customer (see Fig. 4). This uses a combination of abnormality detection logic on the machine's onboard computer and server-side failure diagnosis logic determined from the statistical analysis of large amounts of operational data collected over time. Hosting the failure diagnosis logic on the server side dramatically improves its accuracy by enabling changes to be made as required, such as adding additional conditions or adjusting thresholds. In a trial conducted on machinery in Japan during 2013, there were no incorrect diagnoses among the case of 36 machines that alarm raised.

The system automatically selects where to send notifications based on the level of urgency (potential to cause machine down time) (see Table 1).

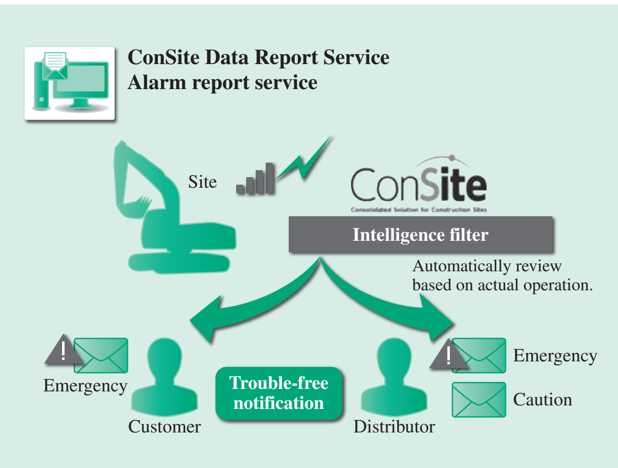

Fig. 4—Operation of Intelligence Filter.
The accuracy of machine alarms is improved as far as possible by filtering them based on past experience.

Table 1. Automatic Selection of where to Send Notifications Based on Level of Urgency
The system automatically selects where to send notifications based on the level of urgency.

	Will problem result in machine downtime?	
	Yes	No
Customer	Emergency alarm distribution	–
Distributor	Emergency alarm distribution	Caution alarm distribution

DEPLOYMENT OF NEXT-GENERATION SERVICE UTILIZING ICT

Changing Role of Distributors

Customer concerns are shifting beyond just machine performance and initial cost to also include reducing overall lifecycle costs. Accompanying this shift, added value from things like ICT, the availability of support from the official distributor, speed of support, and the ability to offer suggestions have become important factors in choosing a vendor.

Challenges for Distributors

Meanwhile, there is also a need to acquire advanced skills to perform failure diagnosis of increasingly complex electronic, hydraulic, and mechanical control. As the speed of support response varies widely depending on the proficiency of the technician, taking or suggesting action based on information obtained using ICT requires not only knowledge of the machine but also IT skills. Because conventional approaches to training and other aspects of human resource development are inadequate for meeting customer needs, action is required on next-generation services that utilize ICT if the technicians who work for the world's leading distributors and their branches and sub-distributors are to provide a consistent level of high quality service to customers.

Response to Challenges

Hitachi Construction Machinery has acquired service know-how in Japan by providing service directly, unlike other construction equipment manufacturers, and deploys this know-how throughout the world. Hitachi Construction Machinery has engaged in development based on the considerations of being useful on-site and acting for the customer's benefit by collaborating with Hitachi Construction Machinery Japan Co., Ltd. on ways of standardizing this know-how so as to provide the same quality of service everywhere. One of the outcomes of this work is the ConSite failure diagnosis manual. Before the full rollout of ConSite, Hitachi Construction Machinery spent several years putting together a technical manual that enables technicians with two to three years of experience at the company to provide the same level of support as more experienced staff. A feature of the manual is that it has been designed to enable technicians to assess situations at a glance, and so that the fault can be dealt with in the shortest possible time in a way that is appropriate to the model type and phenomenon.

The manual is used in conjunction with the alarm report service so that as soon as the distributor receives the report they can immediately start working through a seamless sequence of steps: determining the customer name, serial number, and job site; identifying the phenomenon; looking up the manual; and responding as appropriate. This enables response times to be made much faster than the telephone-based response used in the past (see Fig. 5). Technicians can also look at the monthly report delivered to the customer each month and pass on objective diagnoses and other advice based on numerical data.

Hitachi Construction Machinery uses the term "service automation" for this use of ICT to enable all service staff to provide the same level of service, and sees it as an important policy for strengthening distributors over the medium to long term.

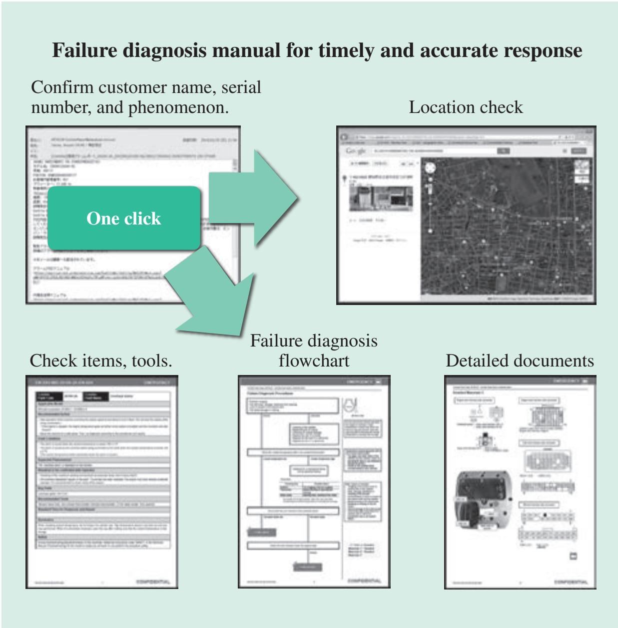

Fig. 5—Integration of Alarm Report and Failure Diagnosis Manual.
The same level of service quality can be achieved everywhere in the world by incorporating experience and other know-how built up in Japan into a manual and standardizing it.

IMPLEMENTATION EXAMPLES

Package Deals

There are numerous examples, particularly in Europe, of customers making use of the features of the ConSite Data Report Service and adopting ConSite in conjunction with an extended warranty, maintenance contract, or other additional options bundled with the service.

These package deals provide greater reassurance and are particularly suited to large customers with planned programs of capital investment. In Japan also, Hitachi Construction Machinery Japan offers packages on its latest models that include standard warranty for a new machine, extended warranty, and maintenance program. Similarly, in Oceania, the ConSite automated data report bundled together in a package with the extended warranty and call center support is offered on new machine sales.

Rather than compelling distributors to adopt particular practices, Hitachi Construction Machinery contracts separately with each distributor regarding the range of services it will offer.

Customer Feedback

Hitachi Construction Machinery has received the following feedback from customers who have adopted ConSite.

(1) It is essential that everyone, including on-site staff, be able to understand what the data means so that it can be followed up with action.
(2) The reports provide a lot of usable data.
(3) Use of color presents information on daily operating hours at a glance.
(4) It is helpful to get a detailed picture in 15-minute intervals. This highlights opportunities for improvement in the behavior of individual operators by, for example, showing who starts their work on time and who does not.

(5) The proportion of non-operating time contains hints about how to improve things like operational efficiency and fuel consumption. While it is difficult to determine what constitutes an appropriate value, determining this is part of our own (the customer's) know-how.

Large customers in Japan who were the early adopters of the service commented on things like the reports being automatically provided on-time each month and their appreciation of the oversight mechanisms. They also requested proposals and the holding of regular meetings with site staff using information provided by Hitachi Construction Machinery Japan. Overall, the feedback indicates that the service contributes to higher levels of customer satisfaction, with the level of orders for services and parts from customers who have contracted to receive ConSite data reports having increased subsequent to their starting to receive the service.

Number of Contracts

As of the end of February 2015, the number of machines for which the ConSite service was available totaled 99,750. While Hitachi Construction Machinery had set a target of obtaining contracts for 5% of these, because many distributors in different parts of the world wanted to offer the service on all new machine sales, the actual number of contracts totaled 14,990, reaching the upwardly revised target of 15% of the above machines.

Outside Japan, trial installations and full-scale installations have commenced in the developed economies of Europe, Oceania, and elsewhere, and also in emerging economies such as China, Turkey, Kazakhstan, Kenya, South Africa, Thailand, Malaysia, and Indonesia. There is particularly strong interest in fuel consumption monitoring from customers in Europe, the UK, Asia, and Oceania.

CONCLUSIONS

As use of ConSite extends worldwide in the future, Hitachi Construction Machinery intends to utilize feedback on the use of machinery in different ways and in different environments, as well as feedback from customers and distributors, to improve the accuracy of portent diagnosis (warning sign diagnosis), lifetime prediction, and similar analyses.

Hitachi Construction Machinery also plans to add a number of new options to the service by expanding the scope of the data being analyzed to enhance the identification of complex interrelationships between different types of operational data. By continuing to work in conjunction with Hitachi, Ltd., Hitachi Construction Machinery Co., Ltd. aims to take advantage of the comprehensive capabilities of Hitachi.

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Featured Articles

ZAXIS-6 Series Hydraulic Excavators Equipped with Latest Environmental Technology

Hidenori Mano
Kensuke Sato
Katsuaki Kodaka
Takenori Hiroki

OVERVIEW: Exhaust emission regulations are becoming progressively tighter for construction machinery just as they are for ordinary cars, with the Tier 4 regulations introduced in 2011 commencing as the final stage of regulation in 2014. Coinciding with this, Hitachi Construction Machinery Co., Ltd. released the ZAXIS-6 Series. In addition to complying with exhaust emission regulations, this new range of hydraulic excavators incorporates numerous market requirements identified from market research into existing models and demand for lower fuel consumption (energy efficiency performance). Hitachi has also taken steps to utilize information technologies to obtain timely information about vehicle status and provide support. The ZAXIS-6 Series are currently being released in the North American market.*

INTRODUCTION

ALONG with initiatives on a variety of fronts being undertaken in recent years to reduce the load on the environment, exhaust emission regulations for construction machinery, too, are being tightened internationally. In response, Hitachi Construction Machinery has developed the ZAXIS-6 Series of hydraulic excavators designed to comply with new exhaust emission regulations, and released them in North America.

The ZAXIS-6 Series has both systems that are compliant with engine exhaust emission regulations and that achieve low fuel consumption. Hitachi Construction Machinery has fitted the ZAXIS-6 Series with urea-based selective catalytic reduction (SCR) systems to achieve compliance with engine exhaust emission regulations, and made improvements to its existing system to improve fuel consumption. To improve maintenance safety, safety rails have been added on top of the main housing. Hitachi Construction Machinery has also utilized information technologies to improve its Global e-Service in order to enhance vehicle status monitoring and respond more quickly to faults.

Along with adopting the urea SCR system (a new technology), Hitachi Construction Machinery has conducted long-term operational testing of the ZAXIS-6 Series with customers in Japan and overseas to evaluate the practicality of components used for urea handling and their reliability when exposed to urea in aqueous solution.

This article describes the new environmental and energy-efficiency technologies, safety improvements, and use of information technology on the ZAXIS-6 Series (see Fig. 1).

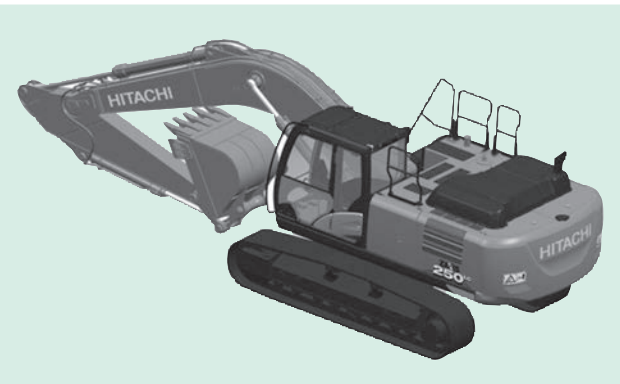

Fig. 1—ZAXIS-6 Series.
The photograph shows a ZAXIS 250LC-6.

NEW ENVIRONMENTAL AND ENERGY-EFFICIENCY TECHNOLOGIES

Urea SCR System (a New Environmental Technology)

The new exhaust emission regulations that entered force in 2014 place limits on particulate matter

* ZAXIS is a trademark of Hitachi Construction Machinery Co., Ltd.

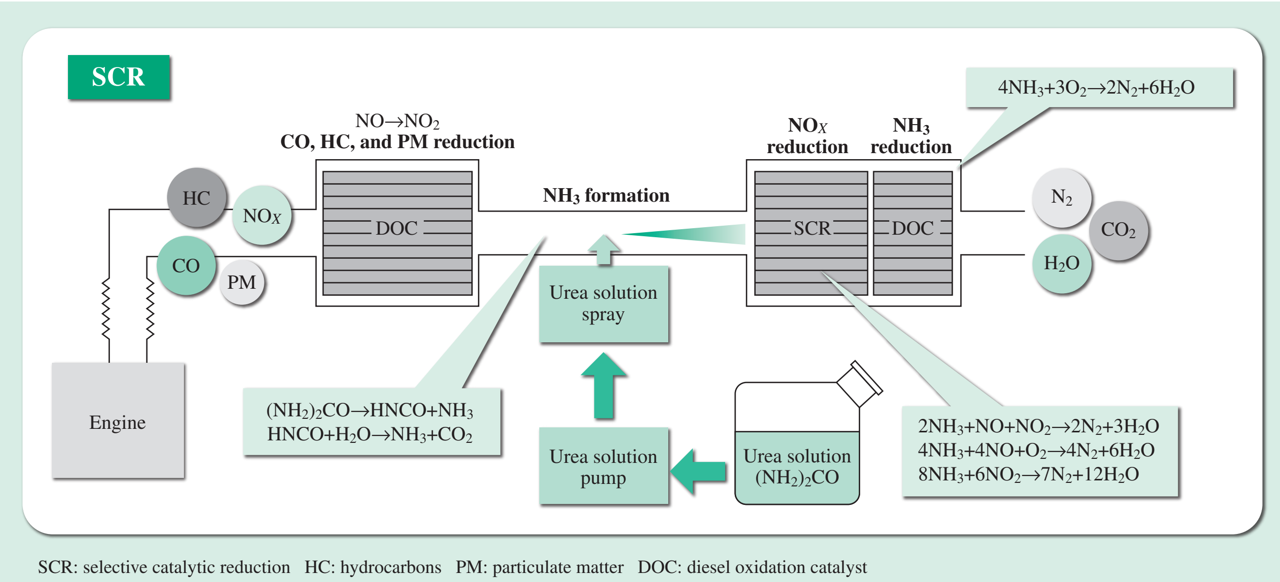

Fig. 2—Overview of Urea SCR System.
Spraying an aqueous solution of urea into the exhaust forms ammonia, which reacts with the NOx and breaks it down into harmless nitrogen and water.

(PM) (0.02 g/kWh, same as previous regulations) and nitrogen oxides (NO*x*) (0.4 g/kWh, one-fifth of previous regulations). That is, the rules on NO*x* emissions have been significantly tightened. Because of the trade-off between the quantities of PM and NO*x* in engine exhaust emissions, there is a limit to how far the engine itself can be improved to satisfy the regulations, and this has made exhaust treatment techniques that use a catalyst to remove pollutants from the exhaust gas essential. Exhaust treatment systems were first fitted to hydraulic excavators on the earlier ZAXIS-5B and ZAXIS-5N Series models. These used diesel oxidation catalyst (DOC) and catalyzed soot filter (CSF) exhaust treatment systems. CSF consists of a ceramic carrier coated with catalyst in which the edges of adjacent cells are alternately sealed off. It significantly reduces PM emissions by filtering PM out of the inflowing exhaust gas as it passes over the ceramic walls between cells.

For the engines in the new ZAXIS-6 Series, Hitachi Construction Machinery adopted a new urea SCR system to comply with the tighter NO*x* emission regulations. The technology for urea SCR is already in use in the truck engine used as a base. However, whereas trucks use CSF and urea SCR together, Hitachi Construction Machinery removed CSF and chose to use DOC and SCR only on the engine for the new hydraulic excavator.

In the urea SCR system, the urea solution is sprayed into the hot exhaust gas inside the exhaust treatment unit to form ammonia. Under the influence of the catalyst, this ammonia then reacts with the NO*x* to break it down into harmless nitrogen and water (see Fig. 2). As a result, in addition to the engine and exhaust treatment unit, the ZAXIS-6 Series also includes a large number of components used by the urea SCR system, including a tank to store the urea solution; a sensor unit to measure its quantity, temperature, and concentration; a pump and hoses to supply it; and the sprayer inside the exhaust treatment unit.

Because the load conditions (engine speed and torque, etc.) and operating conditions (vibration and heat, etc.) for a hydraulic excavator engine are significantly different from those for a truck engine, factors taken into account by Hitachi Construction Machinery during development included studies of equipment layouts, control system matching, and testing under different environmental conditions to ensure the performance and reliability of the engine when used in a hydraulic excavator.

Properties of urea solution include that it freezes at –11°C and that it expands on freezing. Accordingly, the volume of expansion needed to be taken into account when designing the urea solution tank to ensure that it would not fracture should this happen. To decide on the capacity of the urea solution tank, Hitachi Construction Machinery used predictions and verification testing to determine the volume of expansion, satisfied legal requirements for tank capacity, and consulted with customers about how long the machine should be

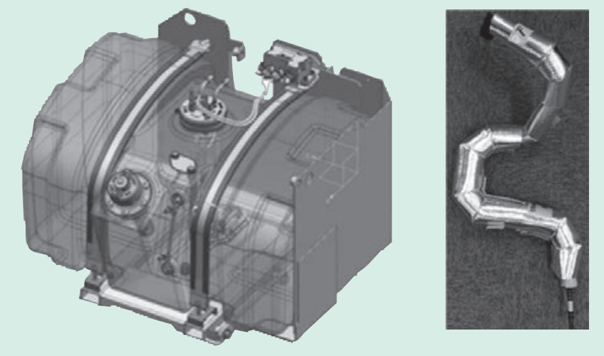

Fig. 3—Urea Solution Tank and Thermally Insulated Urea Solution Hoses.
PE, which is highly resistant to corrosion by urea, is used for the urea solution tank, and PA is used for the urea solution hoses.

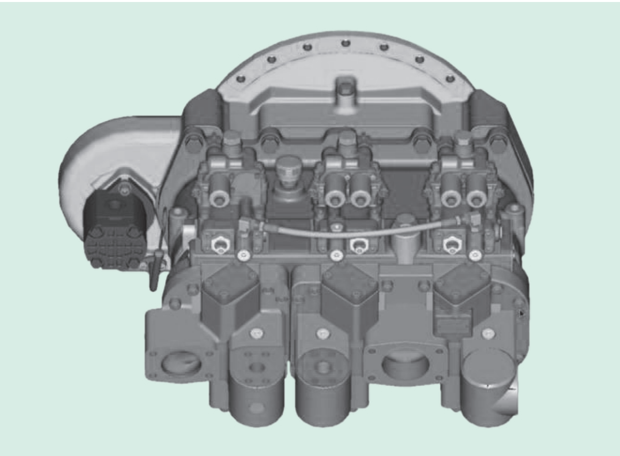

Fig. 4—New Main Pump.
The pump includes an electromagnetic valve that was not present on previous main pumps for optimal control of pump output.

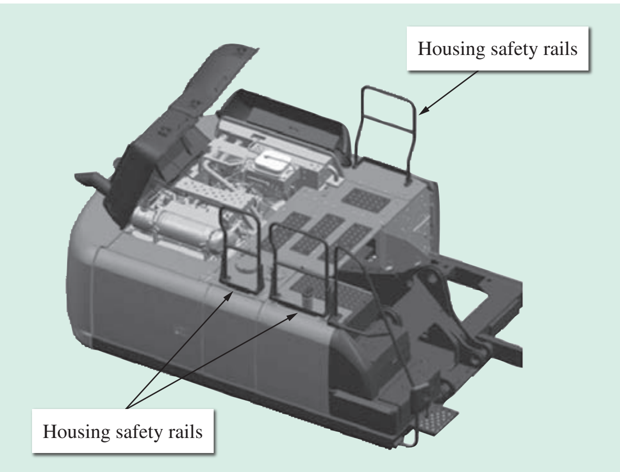

Fig. 5—ZAXIS 240-6 Housing Safety Rails and Engine Cover Structure.
Hand rails have been fitted on the housing access-way for greater safety, and the engine cover structure has been modified to provide better access to the engine and surrounding parts.

able to operate before needing a refill of urea solution (see Fig. 3). The urea solution tank was located at the front right of the excavator and the ease of refilling was assessed during operational trials by customers.

Because urea solution is easily affected by the ambient temperature, ambient temperature needed to be considered when designing the components that handle urea. Thermal insulation was fitted to the urea solution hoses to provide insulation when hot and to maintain the temperature when cold. The minimum thickness of thermal insulation and where to place it were determined based on the ambient temperature where the hose was used and its length.

New Hydraulics System

The new hydraulics system maintains the excellent ease-of-operation of its previous system while also achieving lower fuel consumption through the addition of detailed electronic control (see Fig. 4).

Specifically, because it has better control of pump output, it reduces losses in the hydraulics system by controlling pump output based on control lever position. The control valve spools have also been tuned to achieve optimal balance with respect to the pump output. This significantly improves fuel efficiency compared to previous models.

As a result, the ZAXIS 250LC-6 has 12% lower fuel consumption in economical mode than previous models.

SAFETY AND MAINTENANCE IMPROVEMENTS

Existing safety features have been augmented by new functions to improve safety and maintenance.

Safety Rails on Housing and Engine Cover Structure

To improve the safety of maintenance work on top of the main housing, hand rails that comply with ISO 2867 have been fitted as a standard feature on top of the housing. Meanwhile, the engine cover has been designed to open on the counterweight side to improve maintenance by eliminating the need to work on top of the counterweight and by enabling the exhaust treatment unit cover to be opened and closed (see Fig. 5).

Battery Disconnection Switch

A battery disconnection switch has been provided as a standard feature to improve safety when working on electrical circuits. This makes it easy to turn the power supply on or off (see Fig. 6).

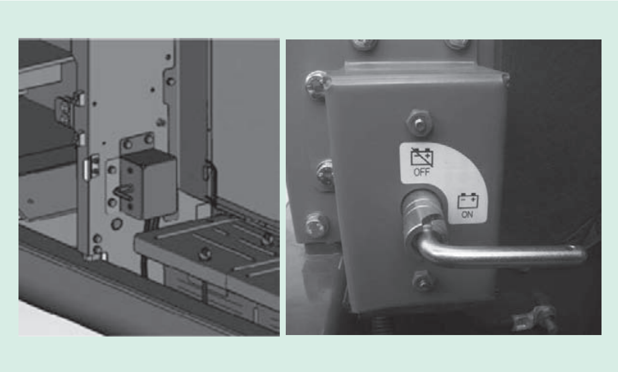

Fig. 6—Battery Disconnection Switch.
The hand-operated switch makes it easy to turn the power supply on or off.

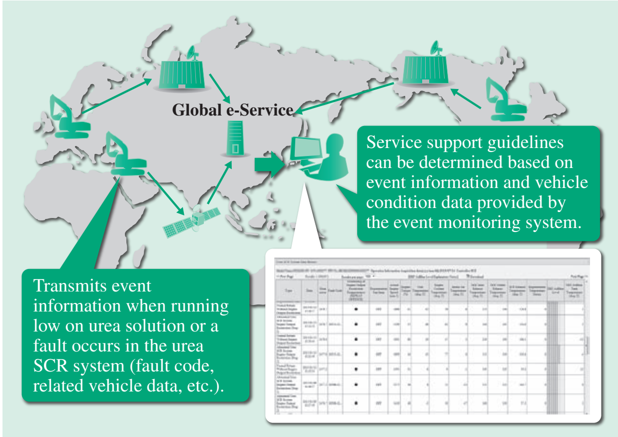

Fig. 7—Overview of Event Monitoring System.
Event information from throughout the world can be viewed from the office.

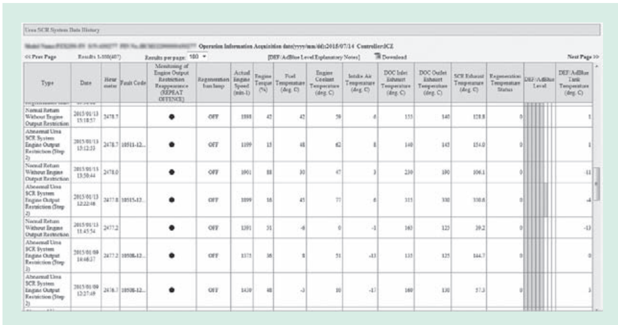

Fig. 8—Event Monitoring System for Urea SCR System.
The status of the urea SCR system can be monitored using event information sent from a machine and the appropriate actions to take are displayed on the screen.

FUNCTIONAL ENHANCEMENTS TO GLOBAL E-SERVICE TO FACILITATE EFFECTIVE USE OF INFORMATION TECHNOLOGY

The new exhaust emission regulations require that engine output be progressively limited if the machine is operated within a range where it will exceed permitted emissions.

For example, if the fault diagnosis function detects that the system cannot spray urea solution, such as when the level of urea solution is low, there is a hardware fault on the urea SCR system, or when an unauthorized modification such as a fake sensor is present, the engine output (torque and revs) must be progressively limited to the bare minimum required. Limiting the engine output in this way restricts the operation of the machine, meaning it cannot be used for its usual work.

Accordingly, one way Hitachi Construction Machinery has made effective use of information technology has been to upgrade the functions of its Global e-Service to enhance vehicle status monitoring and shorten the time taken to respond to faults.

An enhancement made to vehicle status monitoring was the addition of an event monitoring system for the urea SCR system (see Figs. 7 and 8). If engine output is limited due to the level of urea solution being low or the detection of a fault on the urea SCR system, the associated fault code and related vehicle data are sent to the Global e-Service server in realtime.

The event monitoring system uses this server data to provide realtime monitoring of vehicle status. To shorten the time taken to respond to a fault, the system also provides service support guidelines for the urea SCR system based on the fault code and vehicle status information.

CONCLUSIONS

This article has described the new environmental and energy-efficiency technologies, safety improvements, and use of information technology on the ZAXIS-6 Series.

As part of the development and testing of the ZAXIS-6 Series, it has undergone long-term operational trials by customers in Japan and overseas to improve its commercial performance.

In the future, Hitachi Construction Machinery intends to continue with developments that enable it to supply products that are sought by a larger number of users by improving customer satisfaction and strengthening the “Made by HITACHI” brand.

REFERENCE

(1) “Role of Construction Machinery in Building Prosperous and Comfortable Society,” Hitachi Review **62**, (Mar. 2013).

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Featured Articles

EH-3 Series Dump Trucks Enhanced by Comprehensive Capabilities of Hitachi

Naokazu Oda
Takanobu Ikari
Takayuki Sato
Yoichi Kowatari

OVERVIEW: Building on the technologies used in its EH-2 Series, Hitachi Construction Machinery has developed the EH-3 Series of dump trucks with standard features that include an AC drive system and vehicle stability control jointly developed by drawing on the comprehensive capabilities of Hitachi. The EH-3 Series incorporates vehicle stability control to provide more stable driving than previous models while still maintaining the high levels of acceleration and electric braking performance for which they have earned a strong reputation. Hitachi Construction Machinery has also enhanced the competitiveness of the new series by offering it on the market with a choice of engines to suit different customer requirements, with either a Cummins Inc. (standard) or MTU (option) diesel engine able to be mounted in the same truck frame. It is also equipped with a peripheral vision support system to help prevent on-site collisions.

INTRODUCTION

HITACHI Construction Machinery Co., Ltd. released its EH3500ACII mining dump truck with a maximum payload in the 170-t class in September 2008, followed by the 220-t-class EH4000ACII in April 2010. These two models incorporated an alternating current (AC) drive system using insulated-gate bipolar transistors (IGBTs) made by Hitachi, Ltd. that earned them a strong reputation for their driving performance among other features. Subsequently, Hitachi Construction Machinery released the 290-t-class EH5000AC-3 mining dump truck in March 2013. The new model provided greater reliability and driving performance while still maintaining the high level of driving and handling performance provided by the AC drive that were features of the EH-2 Series. The EH5000AC-3 pairs with the EX8000-6, Hitachi's largest excavator, and is experiencing rising demand. It was designed to win market share from its competitors. Hitachi Construction Machinery also released the EH3500AC-3 and EH4000AC-3 in December 2014. These dump trucks are upgrades of the EH3500ACII and EH4000ACII, augmented with features developed for the EH5000AC-3.

The following features are common to all EH-3 Series dump trucks.

(1) Use of technologies from the EH4000ACII
(a) Cab support attached using bolts
(b) Wide cab (same cab used on all models)
(2) Vehicle stability control
(3) Options available for all models in series
(a) Fuel tank suitable for 24-hour operation
(b) Option to use MTU Friedrichshafen GmbH engines
(c) Trolley option
(d) Peripheral vision support system

VEHICLE SPECIFICATIONS

Table 1 lists the specifications for each model.

TABLE 1. EH-3 Series Dump Truck Specifications
The table lists the specifications of the EH3500AC-3, EH4000AC-3, and EH5000AC-3 dump trucks.

		EH3500AC-3	EH4000AC-3	EH5000AC-3
Nominal payload (t)		181	221	296
Payload capacity (m^3)		117	154	202
NMW (t)		141	163	204
Target GMOW (t)		322	384	500
Engine Model/ output (kW)	Cummins	QSKTA50-CE 1,491	QSKTA60-CE 1,864	QSKTT60-CE 2,125
	MTU (option)	12V4000 C21 1,510	16V4000 C21 1,864	16V4000 C20L 2,125
Length (m)		13.56	14.39	15.49
Width (m)		9.13	9.33	9.60
Height (m)		7.00	7.31	7.52
Tire size		37.00R57	46/90R57	53/80R63

NMW: net machine weight GMOW: gross machine operating weight

By keeping the net machine weight (NMW) to a minimum, the EH-3 Series achieves class-leading payloads. Hitachi Construction Machinery also takes advantage of its ability to choose which engines to purchase to offer customers a choice of engines from either Cummins Inc. or MTU, based on considerations such as emissions regulations, fuel costs, and the availability of engine support in the location where the trucks are to be used.

FEATURES OF THE EH-3 SERIES

The features of the EH-3 Series are the result of bringing together the comprehensive capabilities of Hitachi and offer significant potential for differentiation from competing models. The following sections describe the vehicle stability control and the peripheral vision support system features.

Vehicle Stability Control

Hitachi drive control is a vehicle stability control system that uses new control software developed utilizing the comprehensive capabilities of Hitachi and has succeeded in improving productivity and safety by performing precise torque control. Advances in driving control technology of this sort have been achieved as a result of working with technologies of Hitachi, Ltd. honed over many years in electrical control and motor development. The technology not only reduces driver workloads, but is also expected to

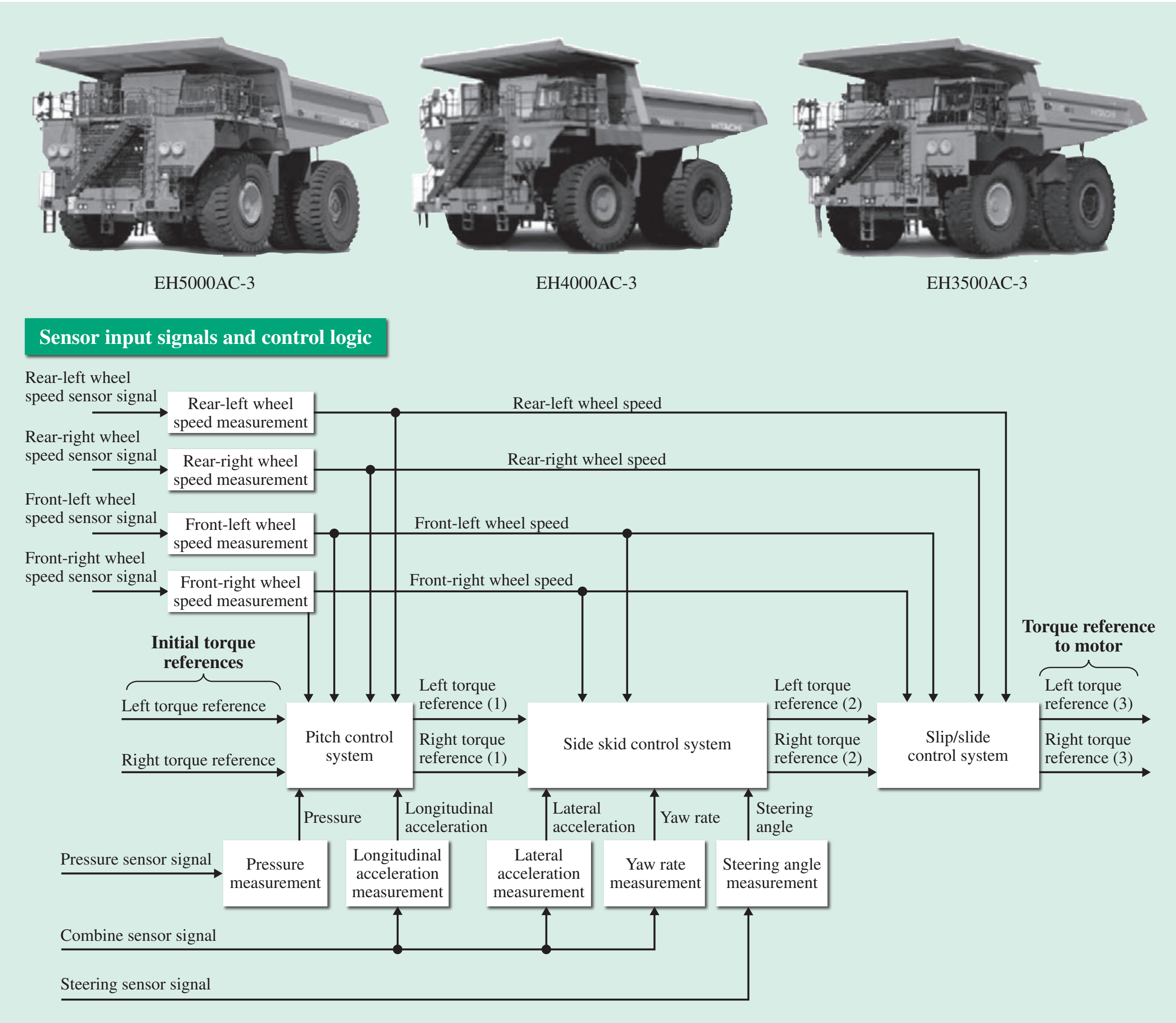

Fig. 1—EH-3 Series Dump Trucks and Configuration of Vehicle Stability Control.
The photographs show the EH3500AC-3, EH4000AC-3, and EH5000AC-3 dump trucks. The diagram shows the sensor input signals and control logic used to implement the Hitachi drive control vehicle stability control system.

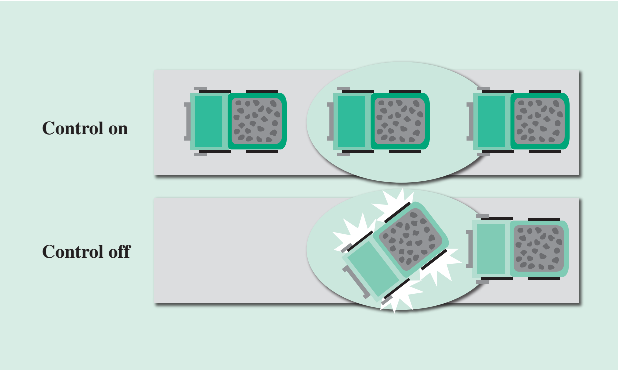

Fig. 2—Slip/Slide Control System.
In addition to providing stable acceleration and braking, the system also reduces tire wear.

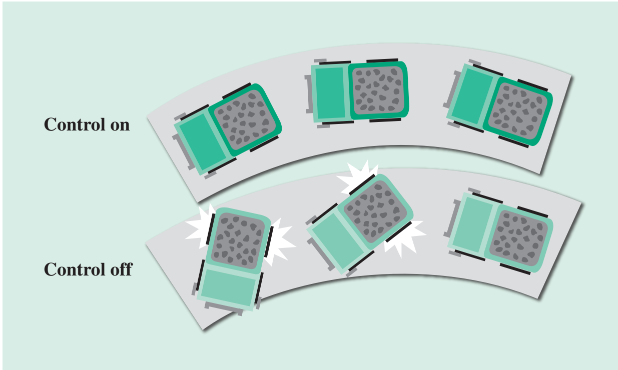

Fig. 4—Side Skid Control System.
The system provides a stable feel to steering when cornering.

reduce customers' management and maintenance costs by reducing accidents and by extending the life of the vehicle and its components thanks to the reduced load on the vehicle.

Hitachi drive control consists of three different types of control: a slip/slide control system, a pitch control system, and a side skid control system. Fig. 1 shows a block diagram of the sensor input signals and control logic used to implement these systems.

(1) Slip/slide control system

This system provides smoother driving together with more stable acceleration and braking, including enhanced responsiveness, by reducing the traction motor torque when it detects the rear axle freewheeling or locking when starting, accelerating, or braking on slippery or uneven roads (see Fig. 2).

(2) Pitch control system

This system reduces cab swaying to improve ride comfort and prevents load spilling by reducing the traction motor torque when it detects pitching in situations such as when driving over uneven roads or when starting rapidly or driving uphill (see Fig. 3).

(3) Side skid control system

This system provides a more stable cornering feel by controlling skidding during cornering to ensure smoother driving by reducing the traction motor torque when the rotation of each of the four wheels indicates that the vehicle has become unstable due to the steering, accelerator, and braking actions of the driver (see Fig. 4).

Peripheral Vision Support System

The potential for accidents such as collisions between dump trucks and service cars, graders, or other equipment is a safety issue at mine sites. Accordingly, there is a demand for systems that can minimize or prevent such accidents. To help reduce such accidents, a peripheral vision support system is available on the EH-3 Series as an option.

The system was developed based on technology for cars developed by Clarion Co., Ltd., a Hitachi Group company. Hitachi Construction Machinery and Clarion also worked together to overcome issues

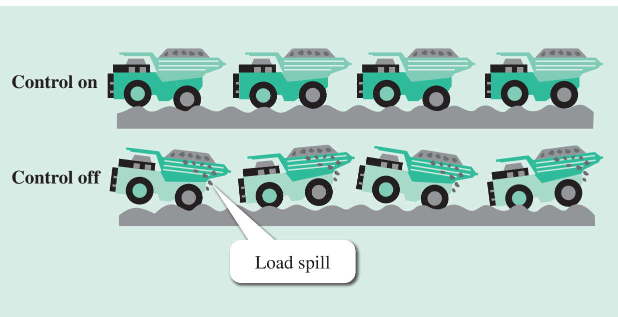

Fig. 3—Pitch Control System.
The system improves ride comfort, prevents load spilling, and reduces stress on the vehicle.

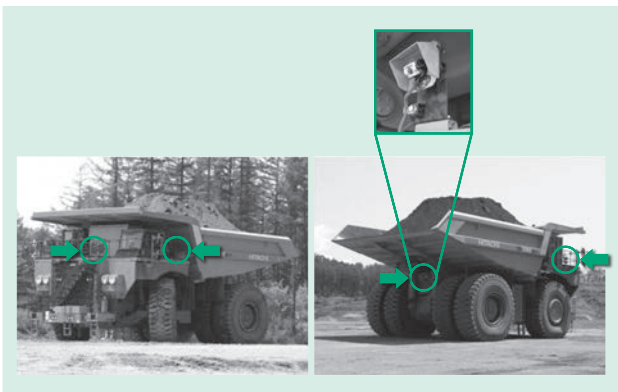

Fig. 5—Camera Locations.
Four cameras are mounted at the front, rear, and sides of the vehicle. The photograph shows an EH5000AC-3.

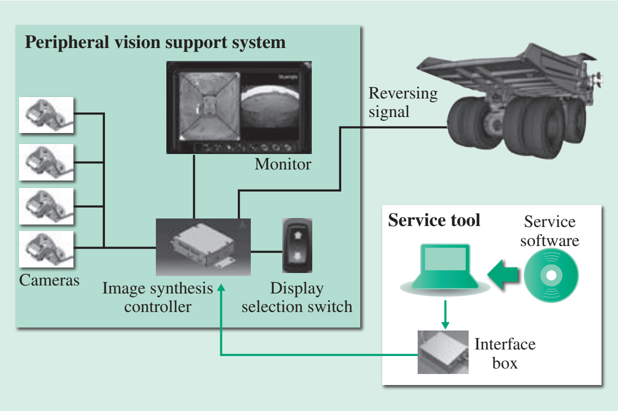

Fig. 6—Configuration of Peripheral Vision Support System.
The image synthesis controller combines images from the four cameras. The driver can use the display selection switch to view what is happening around the vehicle as required.

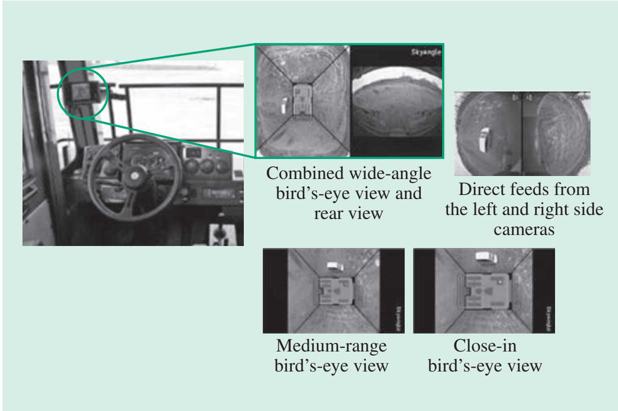

Fig. 7—Display Monitor Mounting Position and Example Display Images.
Images from the four cameras are combined to provide a realtime view of the area around the vehicle and display it on the monitor in the cab.

specific to dump trucks, which are considerably larger than cars, based on technology developed by the Hitachi Research Laboratory of Hitachi, Ltd. The peripheral vision support system consists of four cameras at the front, rear, and sides of the vehicle, an image synthesis controller, display monitor, and display selection switch (see Fig. 5 and 6).

Fig. 7 shows where the display monitor is mounted in the cab and example screens. A display selection switch can switch between monitor images to allow the driver to view what is happening around the vehicle as required. The display can be switched between a number of options, including a combined wide-angle bird's-eye view and rear view, a medium-range bird's-eye view, a close-in bird's-eye view, and direct feeds from the left and right side cameras.

FUTURE DEVELOPMENTS

Deployment on Standard Dump Trucks

The EH-3 Series combines Hitachi's latest technologies to reduce management costs for customers and improve driving performance for drivers. In the future, Hitachi intends to establish a secure position in the market by further improving comfort, reliability, utilization, and serviceability, reducing fuel consumption, and striving to extend the range of special models it can offer for things like trolley operation, low noise, high-altitude operation, and high output.

Autonomous Haulage System (AHS) Dump

Although global demand for mining machinery has recovered from the low it reached in 2003, it has fallen again due to the slowing of economic growth in China and elsewhere. Nevertheless, the long-term outlook through to 2020 is for the market to expand. On the other hand, because mines are characterized by poor living conditions and dangerous work, acquiring staff is becoming more difficult leading to rapid rises in labor costs. In response, Hitachi Construction Machinery is proceeding with the development of autonomous haulage systems for driverless dump trucks. Hitachi's existing technologies include railway traffic management systems, robotics, and car navigation, and the aim is to utilize these together with the comprehensive capabilities of Hitachi to implement such systems in the near future.

CONCLUSIONS

This article has focused on Hitachi drive control and a peripheral vision support system, two features of the EH-3 Series that were developed by drawing on the comprehensive capabilities of Hitachi.

In the future, Hitachi Construction Machinery hopes to enhance Hitachi drive control so that it can balance the loads on the front and rear axles with aims that include reducing tire wear and raising haulage speeds by increasing cornering speeds, and to develop a safety system that adds moving and static object detection functions to the peripheral vision support system.

REFERENCES

(1) K. Imaie et al., "Development of AC Drive Systems for Mining Dump Trucks," Hitachi Hyoron **90**, pp. 1006–1009 (Dec. 2008) in Japanese.
(2) K. Uno et al., "Development of Mining Machinery and Future Outlook for Electrification," Hitachi Review **62**, pp. 99–106 (Mar. 2013).

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Featured Articles

Hybrid Wheel Loaders Incorporating Power Electronics

Kazuo Ishida
Masaki Higurashi

OVERVIEW: Hybrid vehicles that combine an engine and electric drive technology are becoming more common in the automotive industry, with widespread recognition of the excellence of their energy efficiency technologies. In the construction machinery sector, meanwhile, although use of hybrid drive in hydraulic excavators and other vehicles is growing, hybrid wheel loaders have yet to enter full-scale production despite the similarities between their drive trains and those of ordinary cars. Hitachi Construction Machinery Co., Ltd. has previously developed hybrid wheel loaders in the form of a concept vehicle and a vehicle available on limited release. By utilizing the technologies built up through this past experience as a base and making use of the power electronics technology of Hitachi, the company has now developed the ZW220HYB-5B, a hybrid wheel loader intended for full commercial production.

INTRODUCTION

CONSIDERATIONS such as global warming and other environmental impacts due to engine exhaust gases and the problem of oil scarcity have directed attention toward energy efficiency technologies for cars and other vehicles powered by fossil fuels. Hybrid electric vehicles (HEVs) that combine engine and electric drive technology are becoming more common in the automotive industry in recognition of the excellence of their energy efficiency technologies, with electric vehicles (EVs) and fuel cell vehicles (FCVs) also set to enter full-scale production. In the construction machinery sector, meanwhile, although use of hybrid drive in vehicles such as hydraulic excavators and bulldozers is growing, hybrid wheel loaders have yet to enter full-scale production.

Wheel loaders are equipped with a bucket and lifting arms and are used to dig up soil, gravel, rock, or other material, drive it to a dump truck or other form of transportation (carrying the material in the bucket), and then load the material into this other vehicle. Hitachi Construction Machinery models currently in production have standard bucket capacities between 0.3 and 6.1 m^3 (operating weight between 1.9 and 46 t), and are classified according to bucket capacity, including small-sized models with bucket capacities up to 1.3 m^3, medium-sized models with bucket capacities between 1.3 m^3 and 5.0 m^3, and large-sized models with bucket capacities of 5.0 m^3 or larger.

The drive trains of medium-sized and large-sized wheel loaders with a capacity of 3.0 m^3 or more have a four-wheel-drive configuration similar to that used in ordinary cars in which the power from the engine is transmitted via a torque converter and transmission to the axles and then to the tires.

Hitachi Construction Machinery developed a hybrid system with a drive train that combines engine and electric drive technology, similar to an ordinary car. It announced the LX70 medium-sized hybrid wheel loader (1.3-m^3 bucket capacity) as a concept vehicle in 2003, and the L130 large hybrid wheel loader (13-m^3

LX70 (concept vehicle)
- Bucket capacity: 1.3 m^3
- Engine output: 71 kW
- Announced in 2003

L130*
(available on limited release)
- Bucket capacity: 13 m^3
- Engine output: 735 kW
- Announced in 2008

* Developed by TCM Corporation which, at the time, was a consolidated subsidiary of Hitachi Construction Machinery Co., Ltd., and is now known as UniCarriers Corporation.

Fig. 1—Previous Hybrid Wheel Loaders Developed by Hitachi Construction Machinery.
The LX70 was announced as a concept vehicle in 2003 and the limited release of the L130 was announced in 2008.

bucket capacity) as a limited release model in 2008 (see Fig. 1). Based on technology built up from this experience and making use of the power electronics technology of Hitachi, it has now developed the ZW220HYB-5B medium-sized hybrid wheel loader (3.4-m^3 bucket capacity) as a full commercial model with the aims of significantly reducing fuel consumption and carbon dioxide (CO_2) emissions.

This article provides an overview of the hybrid system in the ZW220HYB-5B and describes the results of fuel economy testing and product features.

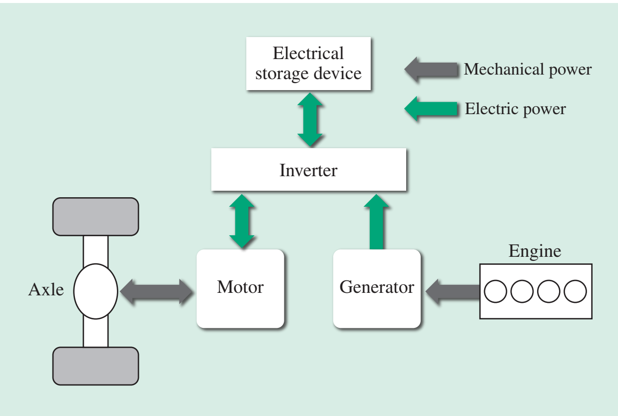

Fig. 2—Conceptual Block Diagram of Series Hybrid Configuration.
Because the engine drives the generator and the electric power from the generator drives the traction motors, a feature of this configuration is that there is no mechanical power transmission coupling between the engine and axles.

OVERVIEW OF HYBRID SYSTEM

As described above, the design of the drive trains used in conventional wheel loaders is similar to ordinary cars. Furthermore, because the dig-carry-load operation of a wheel loader involves frequent acceleration and deceleration, significant reductions in fuel consumption can be achieved by adopting a hybrid drive train, just as is the case for ordinary cars. Hybrid technologies that combine engine and electric drive technologies in a vehicle are generally thought of as being divided into series, parallel, and series-parallel (torque splitter) configurations(1). For the ZW220HYB-5B, the series configuration was adopted based on a study into which configuration best suited a wheel loader, taking account of such considerations as the efficiency of power transmission and the ease of incorporating the system into the vehicle and maintaining it. Fig. 2 shows a conceptual block diagram of the series configuration.

Hybrid System Configuration

Fig. 3 shows a block diagram of the hybrid system configuration on the ZW220HYB-5B. To achieve energy efficiency, the torque converter and transmission used in the past are replaced by a generator and traction drive motors that are operated in tandem with inverters, capacitors (electrical storage devices), and other components. Because it has a series configuration, in which the engine drives the

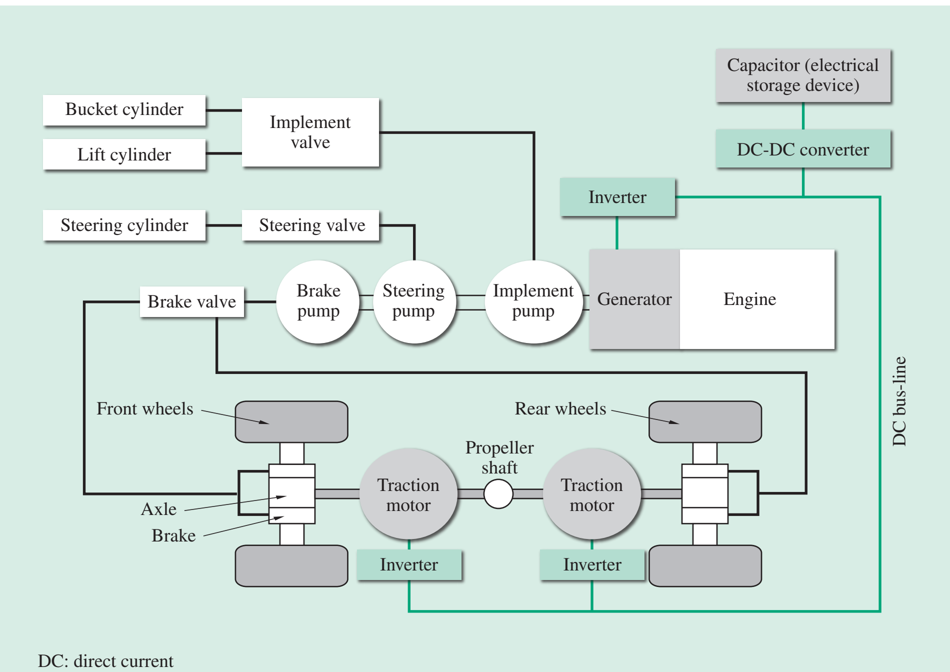

Fig. 3—Block Diagram of ZW220HYB-5B Hybrid System.
Two traction motors are driven by electric power from the generator, which in turn is driven by the engine. The traction motors are used as generators during deceleration to store the regenerative energy as electrical energy in the capacitor so that it can be re-used when accelerating.

generator and the electric power from the generator drives the traction motors, a major feature of the power train is that there is no mechanical power transmission coupling between the engine and axles.

The system uses two traction motors located on the propeller shaft that provides electric drive to the axles. The two traction motors have different characteristics, one with low torque and high speed and the other with high torque and low speed, and the system incorporates a control function that operates each motor at the appropriate efficiency based on the work being performed at the time, whether it be driving at speed or digging and so on.

The capacitor is connected to the direct current (DC) bus-line via a DC-DC converter. It is designed to charge with regenerative energy during deceleration and discharge during acceleration to return this energy to the traction motor.

The hydraulics operate in the same way as on a conventional vehicle, with the engine providing mechanical drive to the hydraulic pump. For safety, the vehicle uses an existing highly reliable hydraulics system for the steering and brakes to ensure that these functions are not lost in the event of a fault in the hybrid system.

Techniques for Using Hybrid Drive to Reduce Fuel Consumption

The following three considerations apply to techniques for reducing fuel consumption by using hybrid drive.

(1) Not having a mechanical power transmission mechanism between the engine and axle improves the efficiency with which engine power is transmitted because it reduces mechanical power losses such as those that occur in conventional torque converters, clutches, and gears.

(2) Because previous wheel loaders have transmitted traction power via the torque converter and transmission, delivering the required driving speed and power is subject to engine speed restrictions. A series hybrid, on the other hand, can alleviate these restrictions, and is designed to improve fuel consumption by having the vehicle controller operate the engine at low revolutions (revs) whenever possible and automatically avoid operating at speeds where its fuel efficiency is poor.

(3) Because the system includes a capacitor, it can efficiently store regenerative energy by operating the traction motors as generators when decelerating and reuse this energy when accelerating. As a result, it is possible to use a smaller engine with a lower output and better fuel consumption than would have been required in the past. As this smaller engine is operated at low revs wherever possible, it also reduces acoustic noise.

Issues with Hybrid Drive

While the adoption of hybrid drive is a major technical development for improving the energy efficiency of construction machinery, it also faces issues with the cost of electrical components, whether their shape and size are appropriate for fitting into existing vehicle bodies, and their reliability and durability.

Because of the significant cost reductions that come from producing electrical components in high volumes, the construction machinery sector is at a major disadvantage because of the small market size compared to the automotive industry[2]. While an advantage of the series hybrid configuration is that it reduces the component count by eliminating the need for a transmission, it also requires heavy-duty inverters, motors, and other components to transmit enough power to drive a vehicle with an operating weight of 18 t or so at high speed. This means that developing drive system equipment that has high output and energy density while still keeping costs down is a major challenge. While Hitachi Construction Machinery has adopted a two-motor design for its traction motors, shifting to a single motor for wheel loaders (which need a large drive torque for digging) would require a motor with an extremely high capacity and a high-output inverter to control it. Because this means high production costs due to an inability to use off-the-shelf components, and because the required components would be too large to fit in the vehicle body, a two-motor design, despite its higher component count, provides a way to balance costs and the ability to fit the system into the vehicle.

Because construction machinery operates in harsh environments, the reliability and durability of electrical equipment is also an issue. Components such as drive motors and inverters need to be at least as reliable as the transmissions used in existing vehicles, with airtight housings designed to be water and dust proof. Hitachi Construction Machinery has also made detailed structural reinforcements to ensure components have the durability to withstand the vibrations that are characteristic of construction machinery.

Hitachi Construction Machinery has also given special consideration to safety. Because the drive train is a fully electric system, Hitachi Construction Machinery has incorporated a variety of features into the control system (including duplicate inputs for device signals, having controllers monitor each other, and the use of monitoring microcontrollers) to ensure that the drive power can be turned off quickly if a problem is detected to prevent it from operating incorrectly. That is, the control system is designed in such a way that dangerous situations will not occur.

ZW220HYB-5B FUEL SAVINGS AND FEATURES

The following sections describe the fuel savings achieved by the ZW220HYB-5B wheel loader using the hybrid system described above, and its product features (see Fig. 4).

Fig. 4—Cutaway Diagram of ZW220HYB-5B Power Train. Despite incorporating the hybrid system, the ZW220HYB-5B has the same vehicle appearance and dimensions as the previous model.

Fuel Savings

In addition to the greater power transmission efficiency achieved by adopting a hybrid drive train, the ZW220HYB-5B also reduces energy losses in the hydraulics and delivers a more appropriate output when digging. As a result, the new model achieved a 31% reduction in fuel consumption compared to the previous ZW220 model (which uses a torque converter) in fuel economy testing conducted using in-house test criteria.

However, because wheel loaders are general-purpose machines used in a wide range of applications (including quarrying, agriculture, industrial waste processing, snow clearing, and cargo handling), their fuel consumption can vary widely depending on operating conditions. The ZW220HYB-5B has a hybrid drive train and generally tends to achieve higher fuel savings the more frequently it is driven. As applications that do not involve a lot of driving or where the vehicle spends a lot of time idling may not deliver worthwhile fuel savings, it is important that it be marketed for use at sites where the work is of a nature that will benefit from its fuel consumption characteristics.

Product Characteristics

In addition to lower fuel consumption, the ZW220HYB-5B also has the following features.

(1) Quieter operation

The smaller engine made possible by use of hybrid drive significantly reduces noise levels in the vicinity of the vehicle.

(2) Continuously variable speed provides stress-free driving

Eliminating the transmission and using an electric motor enables continuously variable speed. Because there is no need for gear changes when digging or driving uphill, for example, and because there is no gear-change shock, this helps reduce driver fatigue.

(3) Potential for energy-efficient operation through independent control of driving and non-driving operations

Whereas the driving speed and implement speed were coupled on previous non-hybrid models where engine revs were controlled by the driver operating the accelerator pedal, on the ZW220HYB-5B this has been replaced by a system based on independent control, where the accelerator pedal controls the driving speed and the implement levers control the implement speed. In the case of loading material onto a dump truck, for example, there are situations in which the driver wants to raise the implement (bucket) quickly at the same time as reducing the vehicle speed as it approaches the truck. On previous models where the driving speed and implement speed were coupled via the accelerator pedal, this would result in drive power losses because it required use of full accelerator at the same time as pressing the brake pedal to slow the vehicle down.

Because the ZW220HYB-5B can control the implement and driving speeds independently, the driver can take his foot off the accelerator pedal to slow down at the same time as maintaining the desired implement speed. This reduces power losses because it enables loading to be performed with the minimum amount of braking, while also helping to reduce driver fatigue by requiring less use of the brake pedal.

CONCLUSIONS

This article has provided an overview of the hybrid system in the ZW220HYB-5B and described the results of fuel economy testing and product features.

As evident in the automotive industry, the use of electric drive is a major trend in the area of energy efficiency technologies for vehicles powered by fossil fuels. Hybrid systems that use electric drive technology are expected to achieve even greater fuel savings in the future as batteries achieve higher energy storage densities and enable greater use to be made of lost energy. In the ZW220HYB-5B system, the engine could be replaced by a fuel cell and there is a potential to achieve zero emissions in the future in consideration of the environment.

Hitachi Construction Machinery Co., Ltd. intends to continue supplying construction machinery that has even greater energy efficiency by making full use of the power electronics technologies of Hitachi.

REFERENCES

(1) N. Mihori, “Introduction to Hybrid Cars,” Gijutsu-Hyohron (Nov. 2009) in Japanese.

(2) M. Edamura et al., “Adoption of Electrification and Hybrid Drive for More Energy-efficient Construction Machinery,” Hitachi Review **62**, pp. 118–122 (Mar. 2013).

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Featured Articles

Use of Simulation in Construction Machinery Development

Kazuhisa Tamura
Akio Hoshi

OVERVIEW: Adopted along with the introduction of 3D CAD, ALD is a technique used by Hitachi Construction Machinery Co., Ltd. during development. It is used to establish predictive techniques that can be deployed in a range of applications by studying phenomena through a mix of experiment and simulation. The company established its Experiment, Analysis & Evaluation Center to adapt the techniques for use on all its products and is working both to improve product quality and development productivity and to determine performance in advance.

INTRODUCTION

THE technique of analysis-led design (ALD) is widely used in the aerospace, automotive, and other industries where it is a key technology providing major improvements in product quality and development productivity. Analysis alone is insufficient for implementing ALD in practice. Instead, it is important that phenomena also be studied through experiments on actual vehicles and that experimental validation is always used to verify analysis methods and the suitability of their results so that they can be established and deployed as practical techniques in other applications. In other words, what is needed is a mix of analysis and experiment.

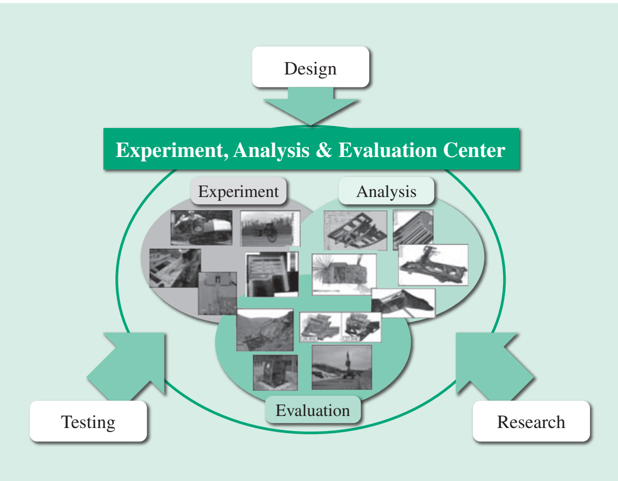

Fig. 1—Establishment of Experiment, Analysis & Evaluation Center (2008).
Hitachi Construction Machinery established the Experiment, Analysis & Evaluation Center as an organization made up of designers with product knowledge and analytical skills, experimental engineers with expertise in experiment and testing, and researchers with specialist knowledge in various fields.

In response to these factors, Hitachi Construction Machinery established its Experiment, Analysis & Evaluation Center in October 2008 as an organization, unlike any other, made up of core staff from various departments and able to combine analysis and experiment in ways that were more closely linked to actual development in order to outperform competitors (see Fig. 1). Since then, they have successfully developed a series of ALD techniques for conducting product development in an efficient manner by determining performance in advance based on the "five-gen philosophy" (a name derived from the Japanese terms for principles ("genri") and rules ("gensoku") and the actual situation ("genjitsu") involving the actual goods or products ("genbutsu") at the actual site ("genba")).

This article describes what has been accomplished by the application to product development of ALD techniques relating to strength and stress analyses and thermal fluid and acoustic analyses that have been incorporating development-stage requirements in a timely manner.

SYSTEM ENHANCEMENTS AND TECHNOLOGY DEVELOPMENT

Internationally, the period around 2008 was one of rapid progress in digital design tools. Because it had become possible to run computer-aided design

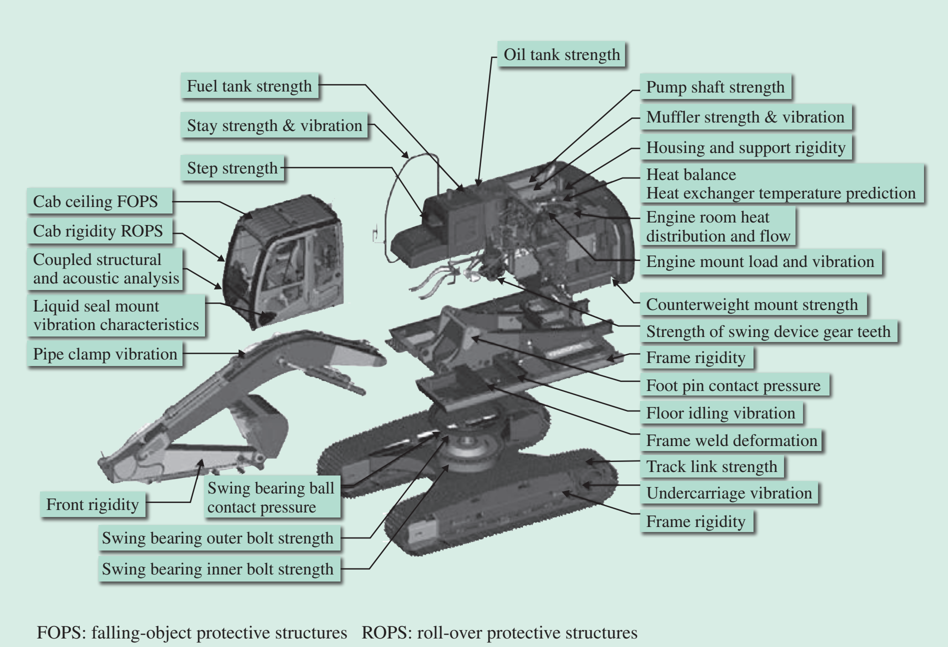

Fig. 2—Roadmap for Development of Simulation Techniques.
The figure lists the areas identified in 2008 as requiring greater analytical precision. The Center prioritized these and set about improving the accuracy of its analysis techniques.

(CAD) and computer-aided engineering (CAE) systems on Windows*1, integration with document handling software was made easier, providing a system environment that enabled the establishment of networks and databases, and gave designers easy access to software ranging from three-dimensional (3D) CAD to CAE. Furthermore, the dramatic boost in computer performance that took place along with the shift from 32-bit to 64-bit operating systems (OSs) provided the ability to run large CAE calculations quickly while seamlessly displaying the results.

These system enhancements enabled Hitachi Construction Machinery to adopt the new NX*2 3D CAD/CAE system for product development from 2009. In 2008, Hitachi Construction Machinery collated a list of areas where analysis precision was inadequate and set about improving the accuracy of performance predictions made using numerical analysis through a program of repeated comparisons of experiments and simulations with the aim of improving development productivity and quality for small and medium-sized excavators (see Fig. 2).

This was a transformative time in the field of CAD/CAE technology during which Hitachi Construction Machinery took active steps to incorporate new technology to improve accuracy and collated calculation standards as part of product development.

*1 Windows is either a registered trademark or trademark of Microsoft Corporation in the United States and/or other countries.
*2 NX is a trademark or registered trademark of Siemens Product Lifecycle Management Software Inc. or its subsidiaries in the United States and in other countries.

USE OF SIMULATION FOR PREDICTION

Linear static analysis based on the finite element method (FEM) has been one of the main techniques used to predict performance at the design stage. The practice in recent years when analyzing the strength of structures has been to study large and detailed models, with a shift from analyzing the strength of individual components to that of entire assemblies (see Fig. 3). In addition to linear static analysis, it has also become possible to study phenomena in detail using multiphysics techniques such as elasto-plastic analysis or coupled analyses of mechanism and structure or fluid and structure. It has also become possible to execute these calculations quickly thanks to improvements in computer performance, providing an environment in which shape design can be performed quickly and reliably using iterative calculations in which these techniques are combined with such methods as optimization or sensitivity analysis. Along with progress in assembly analysis, non-linear analyses that consider contact between parts (assessment of joints) are also becoming increasingly common. New techniques and analytical solvers that can express the pressure and slip between parts in contact are being incorporated into non-linear contact analysis and used to evaluate surface pressure and wear. The period around 2008 was also a time when rapid progress was being made on computational techniques essential to production engineering, such as those for casting simulations and predicting

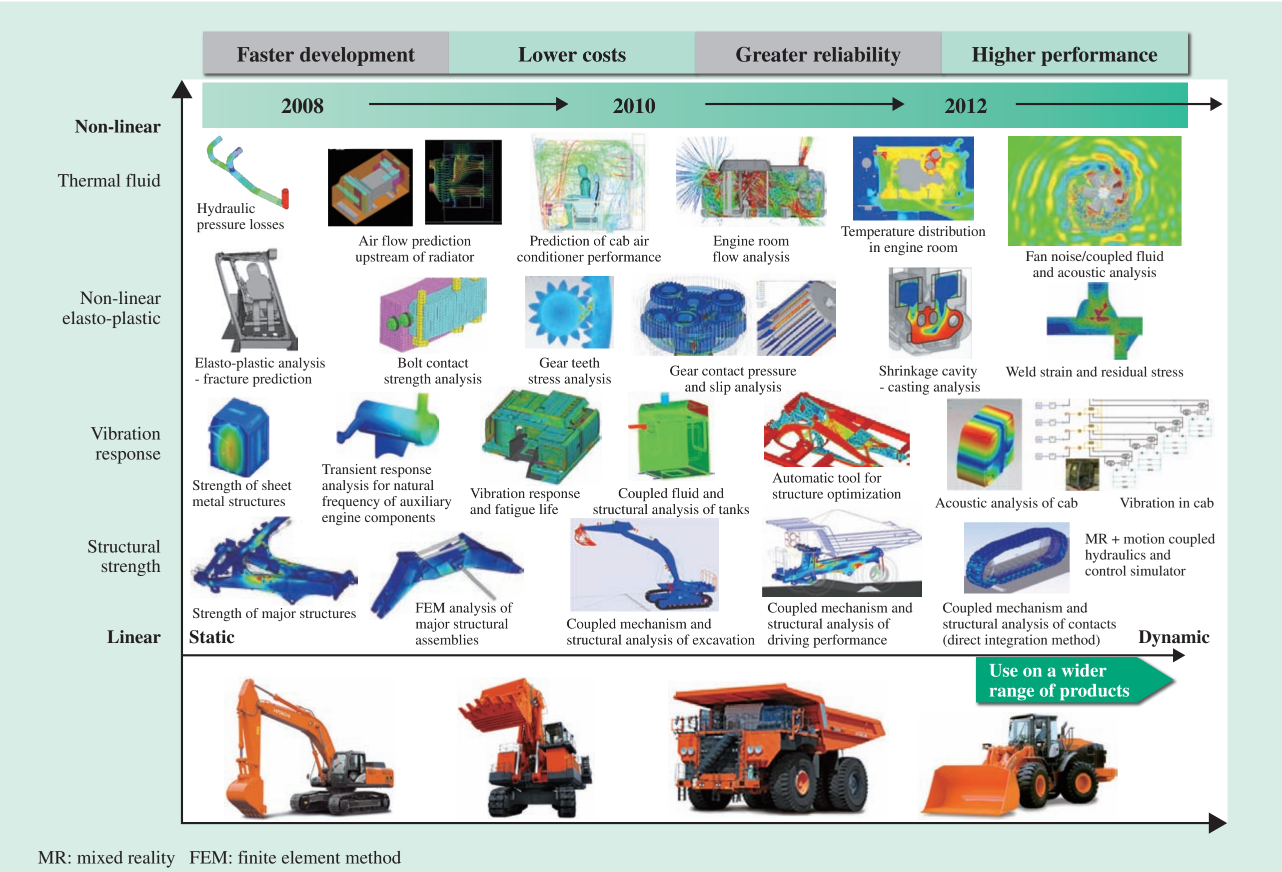

Fig. 3—Development of Simulation Techniques.
Hitachi Construction Machinery has improved analysis accuracy and design productivity through the ongoing adoption of new techniques made possible by recent advances in simulation.

weld strain and residual stress using thermo-elastic-plastic analysis. In the case of vibration analysis, it has become possible to perform transient response analyses of vehicle vibration, including improvements in the accuracy of eigenvalue analysis of structures, and to predict fatigue life based on the stress history obtained from analysis results. In the case of vibration response problems, progress is being made on acoustic analysis and ride comfort assessment calculations for driver's seats. In the case of thermal fluid analysis, the accuracy with which heat balances can be studied has improved, including detailed predictions of the distribution of flow rates, temperatures, and other parameters obtained using large-scale thermal fluid analysis that extends from the air flow upstream of the heat exchanger (using a simple model of the heat exchanger) and directly incorporates a full 3D CAD model of the engine room.

While these analysis techniques have improved dramatically over recent years, the disadvantage of design processes that use ALD is that they invariably increase the amount of work that designers need to perform to build detailed 3D models and to enter data. This work is generally referred to as modeling, and the design process inevitably involves a trade-off between design and modeling. As models become larger, Hitachi Construction Machinery is striving to reduce the amount of time spent on modeling, which is not part of the design, through the simultaneous development of tools for automating modeling and the processing of results.

Use of Linear Static Analysis for Strength Assessment

Reliability testing includes stress measurement tests conducted on various structures. This mainly involves using strain gauges to perform stress measurements at high-stress locations and confirm that the level is within the standard. A lot of time and effort is required if a measurement is higher than the permitted standard because of the need to go back to the design to determine how to resolve the problem, followed by re-testing. How to minimize the number of locations that fail this test and how to minimize the number of

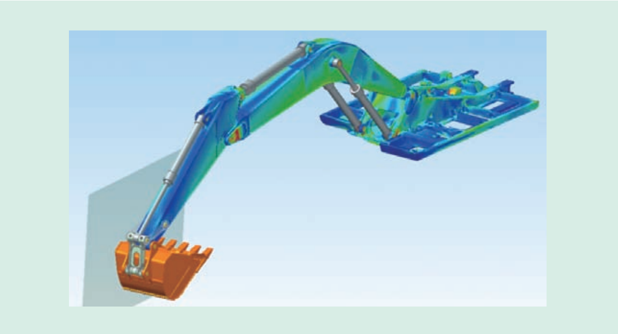

Fig. 4—Stress Analysis of Front Structure and Revolving Frame.
The front structure and revolving frame are joined via a pin, and the analysis provides a detailed representation of load transmission in the vicinity of this joint.

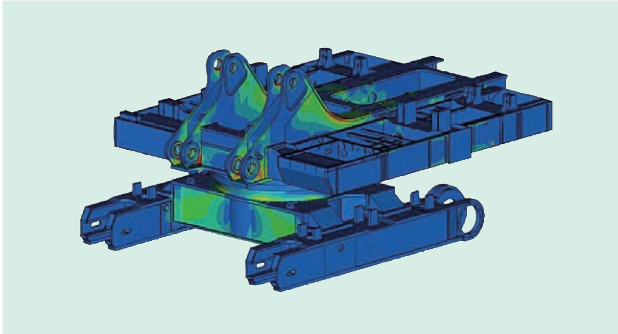

Fig. 5—Stress Analysis of Revolving Frame and Track Frame.
The revolving frame and track frame are connected via a bearing, and the analysis provides a detailed representation of load transmission to the track frame during excavation.

iterations required to pass it are important factors in shortening development times.

The main method used to make design-stage predictions of how a design will perform in this stress measurement is linear static analysis. Since first adopting 3D CAD in 1997, Hitachi Construction Machinery has used FEM-based prediction together with 3D design for components such as the main welded structures, cabs, tanks, housing supports, engine covers, and brackets. With FEM calculations of large models having become possible in recent years, Hitachi Construction Machinery has also adopted the practice of using assembly analyses that combine a number of parts to improve the accuracy of boundary conditions. Figs. 4 and 5 show stress analyses of the front structure and frame, respectively, of a hydraulic excavator. These are typical examples of stress calculations using linear static analysis.

Use of Elasto-plastic Analysis for Strength Assessment

This section describes a technique used to predict the results of tests that involve plastic deformation.

This is mainly used in design-stage investigations associated with the roll-over protective structure (ROPS) standard for cab safety. The requirement is that none of the structure intrudes into the deflection-limiting volume (DLV) when force is applied to a machine cab consecutively from the side, front, and vertical directions. Highly accurate prediction techniques are needed for the pillars and other cab structures because they are press-formed, which means that the time and cost (risk) of corrective work is high compared to other components if changes are required.

The material definition requires entry of the yield stress and the stress-strain curve for plastic deformation. Hitachi Construction Machinery created a materials database for FEM by performing tensile testing of test pieces from the materials used in its machines. The method used to represent material fracture is to treat an element as having lost its rigidity when the upper limit on strain for that element is reached. This method is used for the exhaustive identification of all parts with the potential to fracture and to reinforce them so this does not happen. Furthermore, contact is specified for all parts to represent how panels come into contact with each other or pillars with themselves as plastic deformation progresses.

Fig. 6 shows the results of an ROPS analysis with a sideways load. This indicates how fracture occurs at locations where the strain is highest and exceeds the limit.

Predictive studies are also performed for plastic deformation testing of falling-object protective structures (FOPSs). FOPS testing calculates the extent of deformation of the ceiling and predicts whether

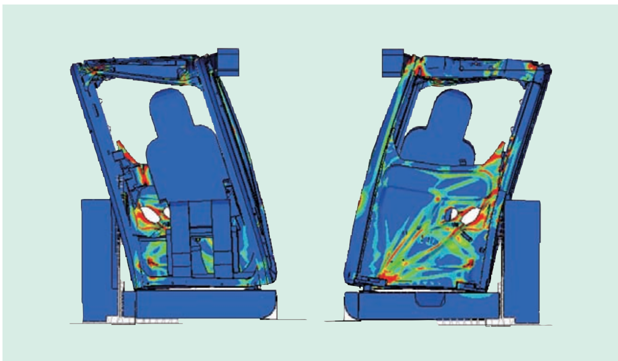

Fig. 6—Elasto-plastic Analysis of ROPS (Side).
A static, non-linear analysis of elasto-plastic deformation and fracture is used to ensure the safety of the cab design in the event of machine rolling over.

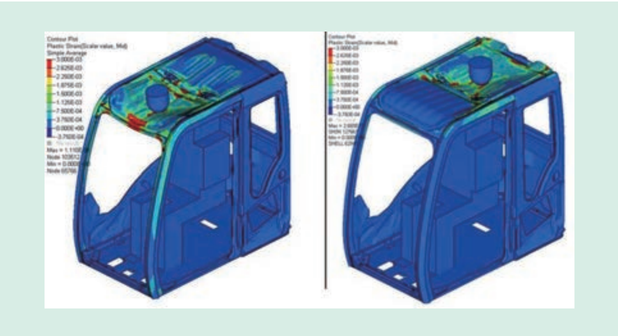

Fig. 7—Elasto-plastic Analysis of FOPS.
The dynamic explicit method for representing elasto-plastic deformation and fracture is used to ensure the safety of the cab design in the event of its being hit by a falling object.

this will intrude into the DLV. The initial conditions for the calculation assume the falling object is an iron ball that has an initial velocity such that its energy matches the required level of energy absorption, and that it is positioned immediately prior to impact. The calculation uses the dynamic explicit method to analyze the behavior before and after the impact on the ceiling, starting from immediately prior to impact (see Fig. 7).

Use of Transient Response Analysis for Vibration Strength and Fatigue Strength Assessment

Construction machinery is subject to severe vibrations and shocks during its use at a worksite, which consists of repeated excavation, loading, driving, and other operations. Strength design for vehicle vibrations has become more difficult in recent years due to factors such as larger engine covers and the supports provided for installing the catalytic converters required to comply with exhaust emission regulations. Predicting the performance of these with good accuracy requires the vibration response to be calculated for input vibrations that vary over time. Two such dynamic analysis techniques are the transient response analysis and frequency response analysis methods, but achieving accurate calculations with these requires that the natural frequency, natural mode, and modal damping ratio used in the model match those of the actual machine. To this end, the accuracy of the calculation model was improved by using experimental modal analysis during the experimental phase (described later in this article). Fig. 8 shows the strength assessment model for the housing cover of the revolving superstructure.

A transient response analysis using actual acceleration measurements from the revolving superstructure as inputs was performed to calculate the vibration acceleration at each location and the stress history. The measured acceleration waveform that was input consisted of 85 s of frame vibration acceleration from the vehicle durability test pattern. A frequency analysis was then performed on the stress values from the stress history to enable the life to be predicted on the basis of fatigue damage. Allowing for variations in reliability, the locations at risk of fracture within the endurance time were displayed (see Fig. 9) and also output as a list. Countermeasures were then implemented at the simulation stage until the risk of fracture was eliminated for all locations prior to the durability test. Furthermore, the entire procedure

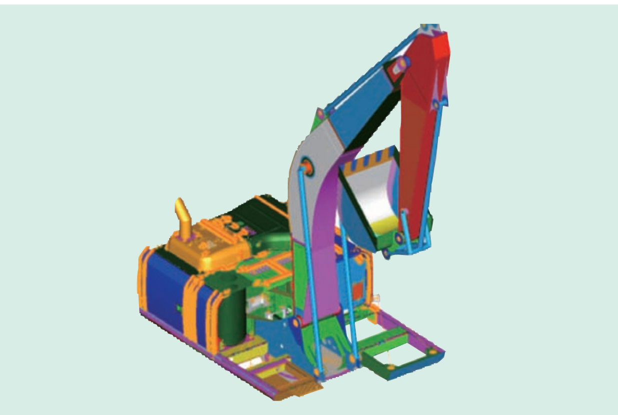

Fig. 8—Transient Response and Fatigue Analysis Model of Housing Cover.
Component life is predicted by using a transient response analysis with vehicle vibration as an input condition to calculate the stress history for each part of the cover, and then converting this into fatigue damage.

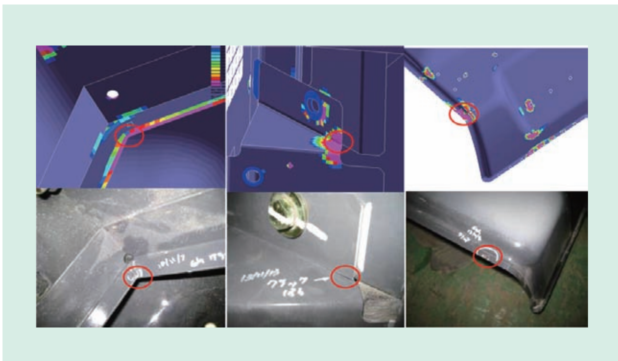

Fig. 9—Fatigue Analysis Results for Housing Cover (Locations where Failure is Predicted).
The results demonstrate that the fracture locations found in actual durability testing match those locations where fracture was predicted to occur within the endurance time.

from transient response analysis to life prediction was automated so that all steps up to results processing could be performed quickly. This was then coupled with an optimization technique that set fatigue damage as the target in an effort to shorten the time required to consider sheet metal thicknesses and shapes.

Use of Coupled Analysis of Mechanism and Structure for Dynamic Stress Analysis

This section describes the coupled analysis of mechanism and structure used to predict the stresses in each part of an operating mechanism made up of multiple parts.

The uses of the technique include analyzing operations that have not yet been measured and determining the stresses resulting from the operation of new parts. Fig. 10 shows an analysis of stresses in the structure of a hydraulic excavator while digging. This treats the front structure and revolving frame and track frame as elastic bodies and uses a coupled analysis of mechanism and structure to predict the stresses that result from the dynamic behavior of this system when connected to the rigid body model of the other undercarriage components.

The main technique used for the deformation of the elastic bodies in the model is the component mode synthesis method that represents the deformation mode as a superposition of natural modes. In this model, however, it is difficult to represent the localized deformation of elastic bodies where they come into contact with each other as doing so requires solving the direct integration with degrees of freedom assigned to each node. Fig. 11 shows a dynamic stress analysis of a track shoe. As shown, localized stresses are generated in the track shoe by the rollers and sprockets and by contact with the road. Because a load is transmitted between adjacent shoes via their link pins, contact is also defined between the pins and bosses. Fig. 12 shows a mechanism analysis in which a planetary gear and shaft are treated as elastic bodies. As with the above example, uses for this analysis include determining how the localized regions of contact change over time and the consequent stresses at the bases of the teeth.

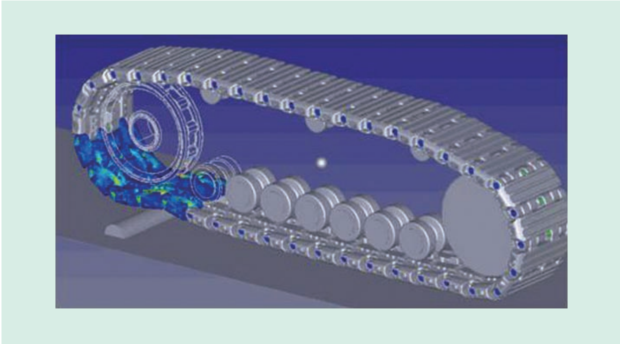

Fig. 11—Coupled Analysis of Mechanism and Structure for Track Shoe Driving over Bump.
The analysis defines the track shoe and the contact between rollers and sprockets, and determines the stress distribution and how stress varies with time in the track shoe as the parts in contact undergo changes over time.

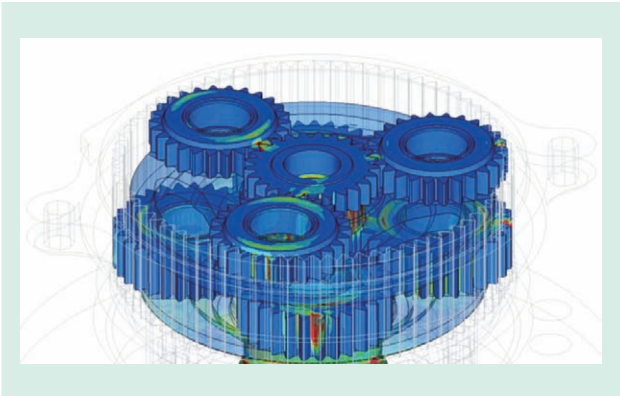

Fig. 12—Analysis of Stress at Base of Planetary Gear Teeth and Contact Pressure.
The analysis predicts the stresses in the teeth and shaft due to the meshing of gears. It is also used to design the crowning dimensions for the gears by also determining the distribution of contact pressure on the teeth.

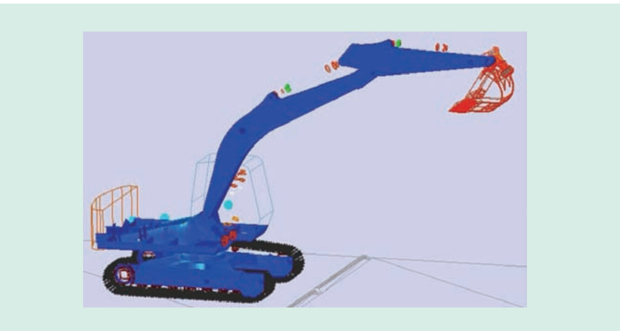

Fig. 10—Coupled Analysis of Mechanism and Structure for Excavation.
The stress history during excavation for each structural component was calculated by incorporating elastic bodies into the mechanism analysis model to perform a dynamic simulation of excavation.

Use of Thermal Fluid Analysis for Evaluating Performance and Reliability

Along with the growing market for hydraulic excavators and other construction machinery in recent years, the uses and operating conditions for these machines are also becoming more diverse, including increasing use in conditions where cooling performance is a challenge. Combined with the greater amount of heat resulting from compliance with exhaust emission regulations, this makes cooling performance improvement and optimization essential. During the design of radiators and other heat exchangers, heat balance analyses using thermal fluid analysis are conducted during the conceptual design stage. Development up to the ZX-5 used a cooling analysis tool developed by the Experiment, Analysis & Evaluation Center that used thermal fluid analysis to determine the combination of the core dimensions of the heat exchanger and cooling air flow under the anticipated thermal conditions. The limitations of this technique were that the engine room was treated as a simplified shape and that the thermal calculation only considered the radiation of heat from the heat exchanger core. When developing the ZX-6, because of the temperature of the urea solution hoses that run through the engine room, the inclusion of equipment sensors, and other factors associated with the inclusion of a urea-based selective catalytic reduction (SCR) system, it was necessary to obtain the air temperatures throughout the engine room in advance. Accordingly, in addition to the existing heat radiation calculation for the heat exchanger, Hitachi Construction Machinery also included a heat damage analysis that could obtain more accurate values for the air temperature in the engine room by specifying the surface temperatures of other heat sources such as the engine, muffler, and hydraulic pump, and the thermal conductivity of non-heat-sources (see Figs. 13 and 14). Because the full 3D CAD model can be used as the shape model in the analysis, it is able to use detailed representations of the shapes of orifices, frames, brackets, and other components. As the air flow from the fan was also calculated by rotating its shape model, this method augments the shape model with detailed predictions of the temperature and air flow distributions in the engine room.

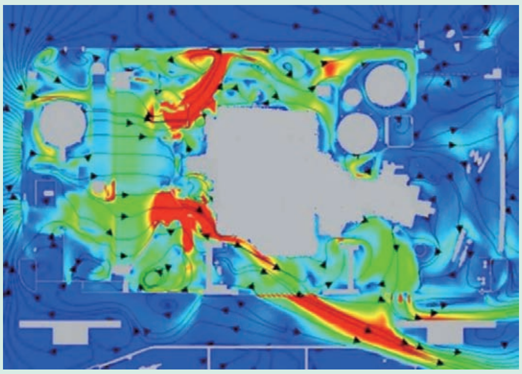

Fig. 13—Air Flow Distribution in Engine Room.
This predicts the distribution of air flow in the engine room based on the predicted flow of air from the cooling fan into the engine room.

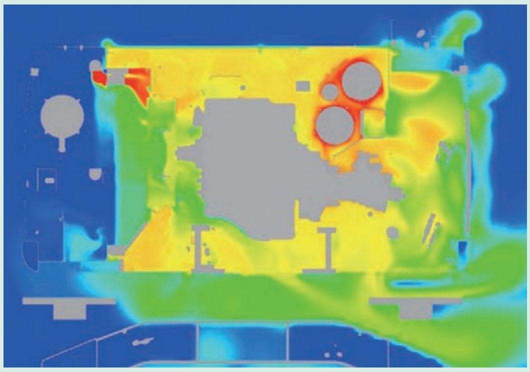

Fig. 14—Temperature Distribution in Engine Room.
This is used to investigate the most efficient means of cooling by using the air flow calculation together with an analysis of the air temperature distribution in the engine room based on specified values for the surface temperature and thermal conductivity of heat sources.

INTRODUCTION OF OBLIGATORY EXPERIMENTAL PHASE AND IMPROVEMENTS IN ANALYSIS ACCURACY

This section describes the experimental phase for collecting basic data to improve the simulation techniques.

While predictive evaluations at the design stage are primarily performed at the Experiment, Analysis & Evaluation Center, as noted above, Hitachi Construction Machinery has established the ability to perform simulations at an early stage in the design process by also assigning staff at the center to each machine under development and having them work together with the machine development teams at the design departments. This enables experiment and analysis staff to share information about the specific issues associated with each machine and perform predictive evaluations of these issues in a planned manner. The evaluation and testing conducted after the prototype is built includes rigorous strain gauge measurements of stress direction at locations with high stress identified by the predictive calculations.

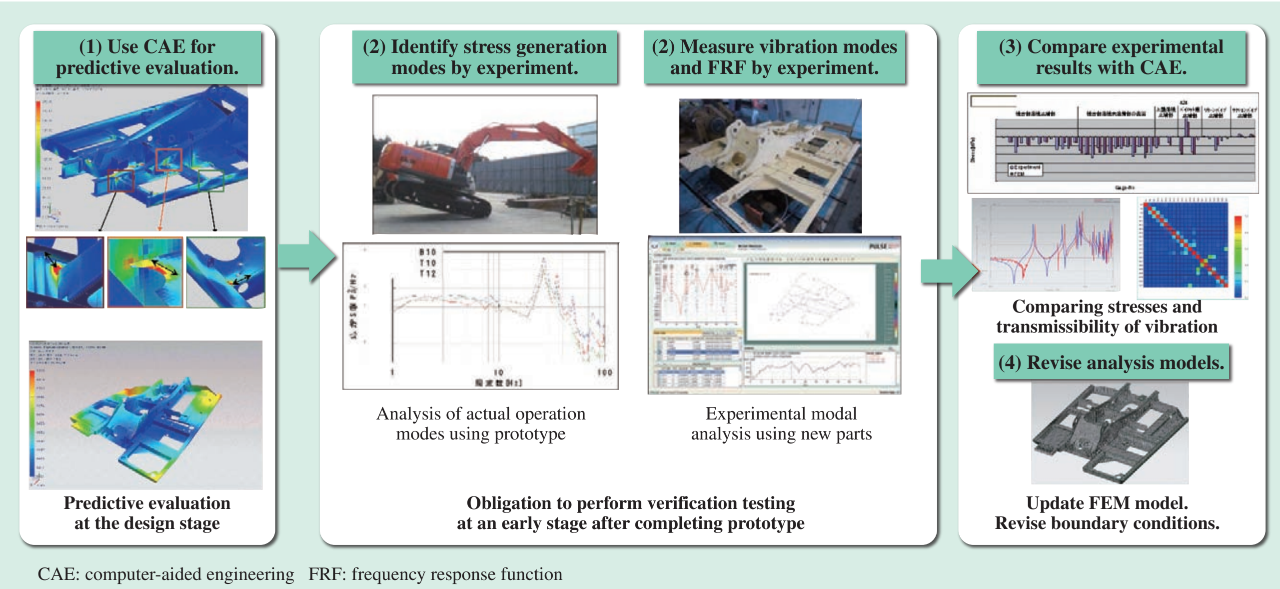

Fig. 15—Use of Experimental Analysis to Improve Simulation Accuracy in Product Development.
Hitachi Construction Machinery has stipulated a requirement that the accuracy of predictive evaluations be verified by conducting detailed experiments soon after the prototype is complete to check the predictions made using simulations at the design stage. It is also making ongoing revisions to its analysis models and improvements in their accuracy.

Since the development of the ZX-6, the work has been obliged to include time for taking measurements during the experimental phase that is separate from evaluation and testing so that detailed experiments involving parameters such as stress, vibration, deflection, and heat can be conducted soon after the prototype is complete. This was done to check the accuracy of predictive calculations and review load conditions and constraints by determining factors such as the deformation modes under high stress, vibration frequency, vibration transmission characteristics, and temperature distribution. When problems are identified during prototype testing, Hitachi Construction Machinery ensures that countermeasures are more accurate and likely to work the first time by re-running simulations with highly accurate calculation conditions (see Fig. 15). To make transient response analyses more accurate, Hitachi Construction Machinery conducts experimental modal analysis using hammering soon after the prototype is available to confirm the accuracy of the natural frequency and natural mode and to determine the modal damping ratio to use as an input for transient response analysis. This succeeds in significantly reducing the time taken and number of iterations required for re-work during ZX-6 development. In this way, Hitachi Construction Machinery has improved the accuracy of analysis by adopting new techniques as required during the development process.

CONCLUSIONS

This article has provided an overview of ALD at Hitachi Construction Machinery Co., Ltd.

Simulation has become an essential tool for quickly bringing products to market that combines performance, quality, and cost. However, real-world development cannot be completed using simulation on its own. Instead, simulation only becomes of practical use when complimented by experiment. Institutions like this one in which experiment and analysis coexist are extremely rare, and Hitachi Construction Machinery intends to take full advantage of the benefits it provides to utilize it on an even greater number of products.

REFERENCES

(1) "From 'Designer' to CAE for 'Design Work'," Mechanical Design **53**, No. 10, pp. 34–37, Nikkan Kogyo Shimbun (Jul. 2009) in Japanese.
(2) A. Yokoyama, Y. Egashira and R. Mizuno, "Simulation Technologies of Collision Analysis for Safety Design Methodology of Automobile," Journal of Society of Automotive Engineers of Japan **65**, No. 1, pp. 59–65 (Jan. 2011) in Japanese.
(3) N. Hato and H. Shimada, "CAE Technology for NVH System Design Approach," Journal of Society of Automotive Engineers of Japan **65**, No. 1, pp. 66–72 (Jan. 2011) in Japanese.

(4) I. Kohri, "Current State of the Computational Simulation Technology in the Automotive Industry," Journal of Society of Automotive Engineers of Japan **67**, No. 6, pp. 47–55 (Jun. 2013) in Japanese.

(5) T. Uchida, "Digital Design," Journal of The Japan Society of Mechanical Engineers, 117, 1148, pp. 56–57 (Jul. 2014) in Japanese.

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Featured Articles

Hitachi Construction Machinery's Global Production System

—Startup of Plant in Russia and Overview of Plant in Brazil—

Toru Takatani
Tomoyuki Koiwa
Masahiro Kawasaki
Shigeki Sasano

OVERVIEW: Hitachi Construction Machinery Co., Ltd. is expanding its business internationally in response to the changing nature of the market for construction machinery. This includes its production division's expansion of local production with the aim of reducing exchange rate risks while also achieving industry-leading QCD on the basis of "local production for local consumption." As a result, the company now has 19 production sites outside Japan, with approximately half of all production taking place at these overseas plants. This growing use of local production started in Europe, followed by North America, China, and Asia. Recently, the company has also opened a plant in Russia to maintain price-competitiveness and improve quality, and it has established a joint-venture company in Brazil with a local partner that includes the construction of a new plant.

INTRODUCTION

HITACHI Construction Machinery Co., Ltd. is expanding its business internationally in response to the changing nature of the market for construction machinery. The proportion of overseas sales has grown from 6%, when the company was established in 1970, to an anticipated near 80% in FY2014.

In terms of production, the company has also transformed its business by shifting from its focus on exporting from Japan toward greater local production. Local production got underway in earnest in the 1980s in response to the high Yen and anti-dumping tariffs. In the late 1990s, Hitachi Construction Machinery commenced production in nations such as Indonesia, China, and India in response to growth in emerging markets. Now, in the 2010s, Hitachi Construction Machinery is commencing production in Russia and Brazil with the aim of achieving industry-leading quality, cost, and delivery (QCD).

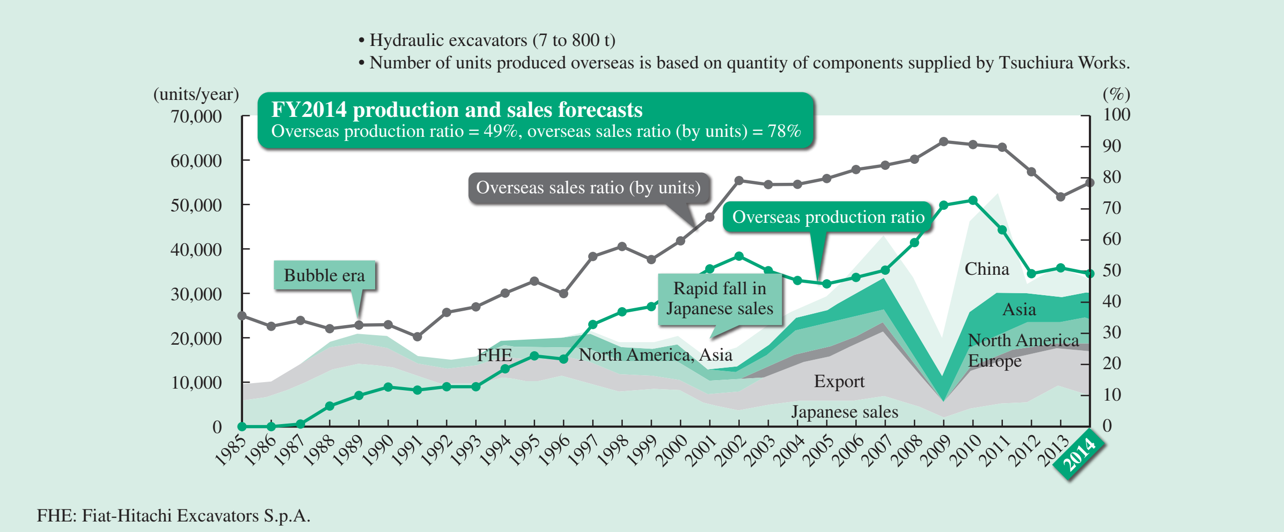

Fig. 1—Ratios of Overseas Production and Sales by Hitachi Construction Machinery.
Hitachi Construction Machinery has transformed itself from a Japanese company to a global company.

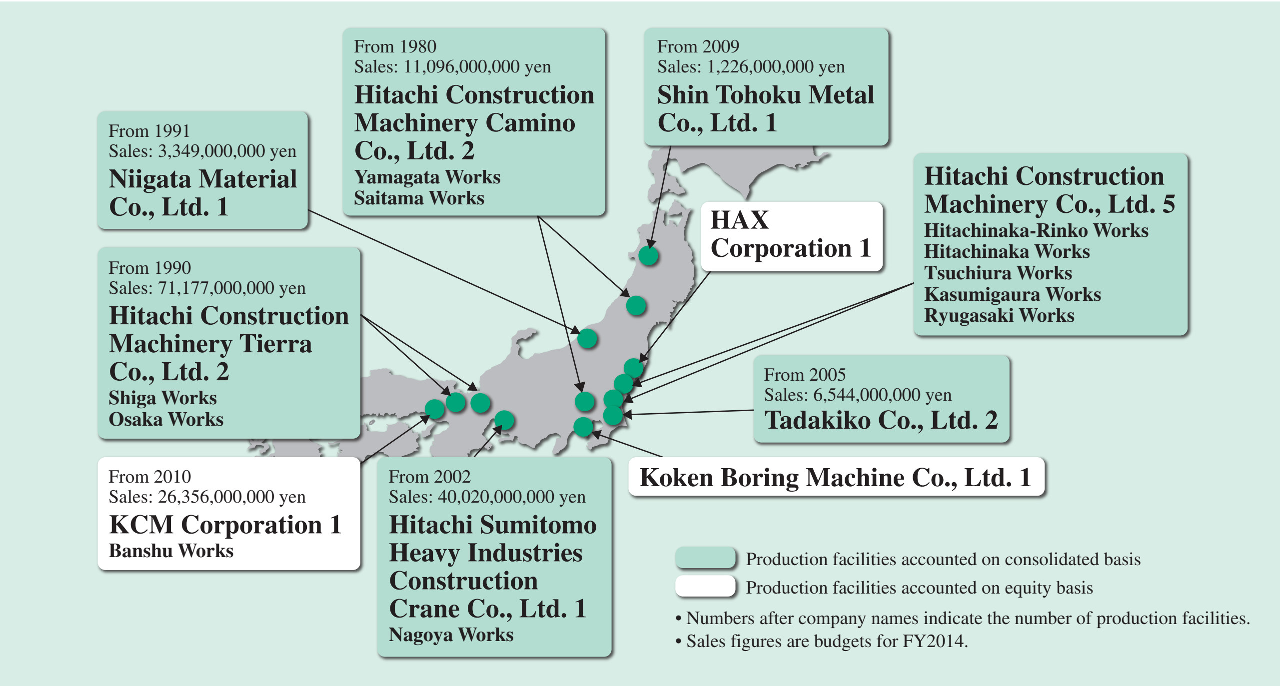

Fig. 2—Hitachi Construction Machinery's Japanese Production Sites.
Hitachi Construction Machinery has 17 production facilities in Japan, including five plants belonging to Hitachi Construction Machinery.

This article looks back at the history of increasing local production by Hitachi Construction Machinery and describes the features of the recently opened plants in Russia and Brazil.

EXPANSION OF OVERSEAS BUSINESS

Fig. 1 shows a graph of the proportions of overseas production and sales (by number of units) of construction machinery by Hitachi Construction Machinery since 1985.

Whereas sales in Japan have continued to decline since peaking in the bubble era, overseas sales have remained on a rising trend. As a result of shifting increasingly to local production as overseas sales have grown, the ratio of overseas production surpassed 50% in 2001, and has remained close to, or above, this level ever since.

As of 2015, Hitachi Construction Machinery has 17 production facilities in Japan and 19 overseas (see Figs. 2 and 3). Broken down by region, these comprise two sites in North America, one in South America, four in Europe (including Russia), five in China, six in Asia (excluding China), and one in Africa.

The following section describes how Hitachi Construction Machinery's operations have changed over time in each region.

Europe

In 1984, the European Community (EC) imposed anti-dumping tariffs on imported machines. This led Hitachi Construction Machinery to adopt an "insider" strategy of moving to local production. Local production and sales in Europe commenced in 1986 with the establishment of Fiat-Hitachi Excavators S.p.A. (FHE) as a joint venture with Fiat S.p.A. Hitachi Construction Machinery initially owned 44% of the company, a stake that it subsequently reduced to 36%.

A problem arose in 1999 with the purchase by Fiat of a competing company, Case IH, leading to the joint venture contract being dissolved in 2002 and Hitachi Construction Machinery continuing its European business on its own.

Building on the existing operations of Hitachi Construction Machinery (Europe) N.V. (HCME), which had been the lead distributor in Europe from its base in the Netherlands since 1972, a new plant was opened in Amsterdam in 2003 for the production and sales of Hitachi-branded machinery under Hitachi Construction Machinery's own management.

While the greatest fear that accompanied the shift to operating independently was the potential loss of support from FHE dealers, in fact not only did most dealers choose to stay with Hitachi Construction

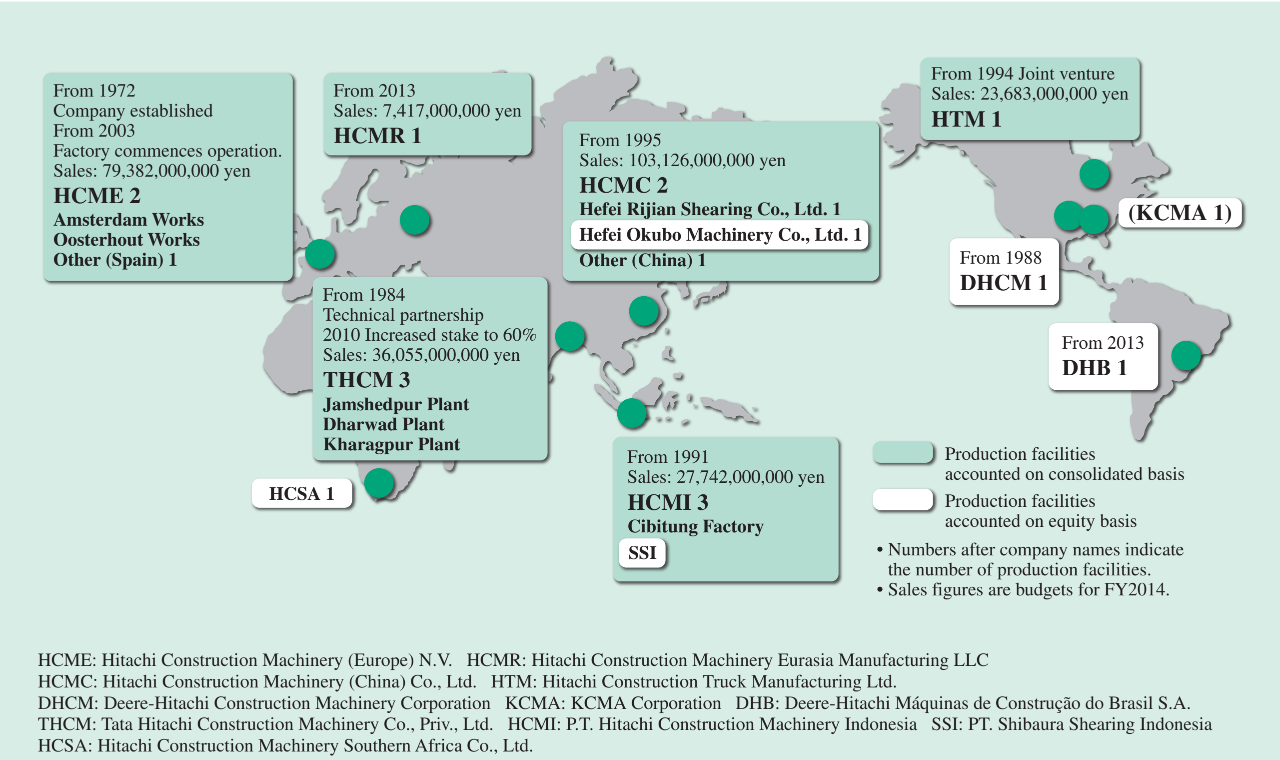

Fig. 3—Hitachi Construction Machinery's Overseas Production Sites.
Hitachi Construction Machinery has 19 overseas production sites.

Machinery, but a major dealer that handled competing brands also chose to represent Hitachi Construction Machinery. This indicated how well-perceived Hitachi Construction Machinery was in the market for the excellence of its machinery, its attitude to its customers, and the name-recognition of its brand.

North America

Hitachi Construction Machinery decided to commence local production in the USA after the profitability of exporting was hit badly by the sharp appreciation in the Yen against the US dollar in the late 1980s. In 1988, Deere-Hitachi Construction Machinery Corporation was established in North Carolina as a 50-50 joint venture with Deere & Company, with which Hitachi Construction Machinery already had close relations including the supply of products on an original equipment manufacturer (OEM) basis. The new company produced medium-sized hydraulic excavators under both the Hitachi Construction Machinery and John Deere brands.

Euclid-Hitachi Heavy Equipment, Inc. (EHHE) was established in 1994 as a joint venture with Volvo Michigan Euclid (VME) (subsequently Volvo) and commenced production of extra-large rigid dump trucks in Canada. Hitachi Construction Machinery subsequently acquired full ownership of EHHE in 1998 and went on to re-launch it as Hitachi Construction Truck Manufacturing Ltd. (HTM) in 2004.

China

Hitachi Construction Machinery commenced local production in 1995 by teaming up with Hefei Mine Machinery, China's second largest manufacturer, to establish Hefei Hitachi Excavators Co., Ltd. as a joint venture company in which Hitachi Construction Machinery had a majority shareholding (55%). Hitachi Construction Machinery bought out Hefei's stake in 1998 to make the company fully Japanese-owned and enable it to be managed independently.

The company was renamed Hitachi Construction Machinery (China) Co., Ltd. (HCMC) in 2005. Its production capacity at this point was second only to Japan. In addition to its main product of medium-sized hydraulic excavators, it also produced mini-excavators and mobile cranes. As a result of ongoing work on quality improvement, the company has also become a supplier of high-quality and low-cost components to other plants, particularly welded structures.

In 2013, Hefei Okubo Machinery Co., Ltd. (HOM) was established as a joint venture with Okubo Gear Co., Ltd., a supplier of hydraulic equipment, and commenced production of hydraulic components in China.

Asia (Excluding China)

Hitachi Construction Machinery commenced production in Indonesia and Malaysia in 1991 in partnership with local investors. P.T. Hitachi Construction Machinery Indonesia (HCMI) subsequently made good progress, producing not only medium-sized excavators but also welded structures, modules for very large excavators, and other components for supply to other facilities.

Telco Construction Equipment Co., Ltd., a joint venture in India with Tata Motors Limited, was launched in 1999. While Hitachi Construction Machinery only had a 20% stake to begin with, it increased this to 40% in 2005 and 60% (majority ownership) in 2010. A new plant on a site of approximately 1,000,000 m^2 was established in Kharagpur in eastern India in 2009, becoming a major plant supplying medium-sized hydraulic excavators not only to the Indian domestic market but also (from 2014) to the Middle East, Africa, and elsewhere.

Other Regions

Brazil, Russia, India, and China are collectively known as the BRIC nations. Prompted by the potential for tax-related risks, Hitachi Construction Machinery started production in 2013 in the two BRIC nations where it did not already have local production operations, namely Russia and Brazil. Hitachi Construction Machinery currently does not manufacture in Africa or Oceania.

The following sections describe the plants in Russia and Brazil, each of which was established based on a different approach.

COMMISSIONING OF PLANT IN RUSSIA

With their large land area and extensive natural resources including oil and gas, Russia and the other nations of the Commonwealth of Independent States (CIS) have been experiencing robust demand for construction machinery for use in areas such as urban earth works, pipeline construction, and mine development. Hitachi Construction Machinery has been supplying machinery to these countries for more than 30 years, primarily by importing fully assembled machines from Japan. Total sales to date amount to more than 16,000 machines.

However, Hitachi Construction Machinery embarked on a serious investigation into becoming an "insider" in response to import restrictions and encouragements for domestic production introduced by the Ministry of Economic Development of the Russian Federation that came into force in 2009.

A decision was subsequently made to build a factory for medium-sized excavators in Russia. The plant commenced shipments in June 2014.

The following sections describe Hitachi Construction Machinery's plans to become an "insider," the factory commissioning process leading up to the commencement of full-scale production, and features of these.

Aim of Becoming an "Insider"

Price competitiveness is essential if customers are to be able to purchase and use high-quality products on a regular basis. Tariffs and freight costs are among the factors that influence price competitiveness.

While Russia currently imposes a tariff of 5% on imports of fully assembled hydraulic excavators, past threats to introduce regulations that would increase this by double or more have provoked concern from Hitachi Construction Machinery about losing price competitiveness.

To counter this, Hitachi Construction Machinery has sought to reduce tariff payments by becoming an "insider" with a high proportion of locally produced parts. In other words, by importing parts only and in as small a number as possible.

Meanwhile, although average freight costs vary depending on the destination and the mode of transportation used, making major reductions in these under the conditions that have prevailed to date has proved difficult.

Another problem with the import of fully assembled models is that they are liable to be held up at the port or suffer damage or exterior deterioration of parts during transportation by sea, truck, or rail, with a notable loss of finish quality when the machine is handed over to the customer. In the case of transportation by rail in particular, the machines need to be partially disassembled for reasons of size and secured to the wagon, and they invariably suffer from exposure to things like dirt and weather when transported over long distances.

Accordingly, as part of the shift to an "insider" approach, Hitachi Construction Machinery set out to reduce the total cost from the start of production through to delivery to the customer and to improve the quality at the time of delivery by significantly improving transportation conditions.

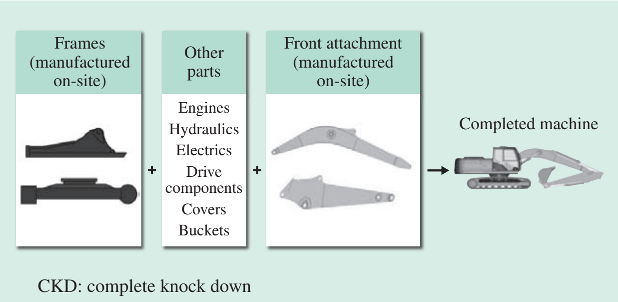

Fig. 4—Parts Supplied in CKD Form or Manufactured Locally.
A CKD production model with large and heavy frames being manufactured on-site was adopted to reduce freight costs and increase the percentage of locally produced parts.

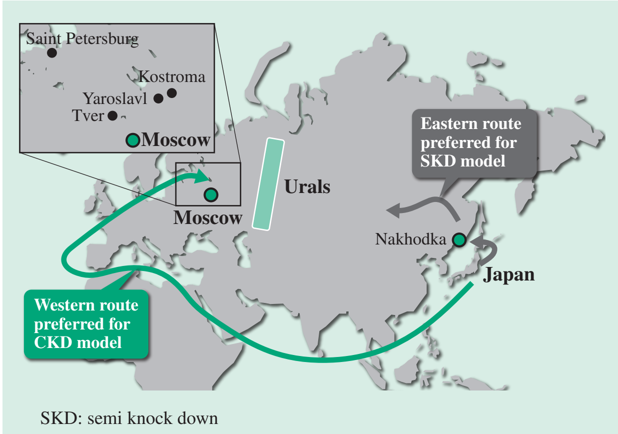

Fig. 5—Transportation Routes Selected Based on Economic Assessment.
For reasons of economics, Hitachi Construction Machinery chose to ship parts via the western route and construct its production site in the vicinity of Moscow.

Production Model and Locally Produced Components

First, a complete knock down (CKD) production model[*1] was adopted to achieve a high proportion of locally produced parts, with as much as possible of the frame and front attachment being built at the plant (see Fig. 4).

Second, ongoing imports were still required for precision components such as those used in the engine and hydraulics, with these primarily being produced in bulk in Japan.

Based on the results of the current study, it was found that the best economics were achieved by adopting the semi knock down (SKD) model[*2] for products shipped via the east and the CKD model for those shipped via the west (see Fig. 5).

Third, to increase the number of parts manufactured locally, parts procurement includes working with local suppliers and other Japanese companies with operations in Russia to increase production (see Fig. 6).

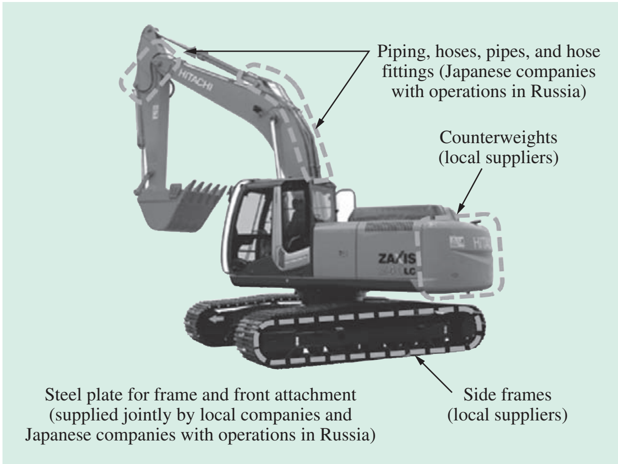

Fig. 6—Local Parts Procurement Plan.
Hitachi Construction Machinery is working to increase local production of parts in collaboration with suppliers.

Site Selection

While Hitachi Construction Machinery surveyed approximately 40 potential sites across Russia, the final comparison was between a shortlist of five cities in the vicinity of Moscow, chosen in part because of the proximity of other manufacturing operations and convenient port access, and also because approximately 80% of hydraulic excavator sales are made west of the Urals (see Fig. 7).

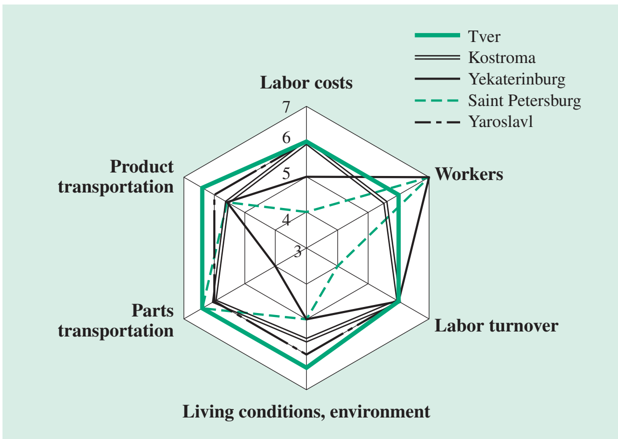

Fig. 7—Comparative Assessment of Potential Sites (Cities).
Hitachi Construction Machinery selected Tver because of its transportation advantages and its favorable conditions for operating a production facility.

*1 A production model that involves handling non-assembly processes such as the welding and painting of the frame, front attachment, and other components, and also performing the bulk of assembly work while procuring parts on a function-by-function basis.
*2 A practice that involves only handling the final assembly, with components provided on a function-by-function basis in pre-assembled semi-finished form, without including processes such as welding and painting.

In addition to the site comparisons, Hitachi Construction Machinery also undertook a detailed survey before finally deciding on Tver. Of the major factors in the decision, the most important was the significant benefits for the transportation of products and parts. Other factors include that Tver is one of Russia's industrial cities, with a technical university and local companies producing goods such as rolling stock (freight cars) and excavation machinery, few foreign companies, and a regional government that was proactive about attracting foreign direct investment.

Company Formation and Commencement of Operations

Past construction of large-scale production facilities by Hitachi Construction Machinery had been undertaken first in partnership with local companies, and then had been progressively expanded. This, in contrast, was the first time Hitachi Construction Machinery had constructed a greenfield factory on its own, although its operations in Russia included having already established a sales company in Moscow.

While work proceeded on company formation, establishing management structures, and preparing for production, differences of understanding arose regarding the preparation of contracts with the relevant agencies and companies, the complex legal system, and the large amount of paperwork associated with obtaining certain approvals and getting hooked up to infrastructure, and contractual responsibilities to fulfill obligations on time.

While more effort than expected was required to get things done while learning to understand and accept this situation, Hitachi Construction Machinery worked to resolve the issues one by one.

Factory Size

The factory is intended to produce hydraulic excavators in the 20- to 33-t range, the company's main product in Russia and the CIS market.

Based on demand forecasts, the factory has an annual capacity of 2,000 units, with a floor space of 32,000 m^2 on a 400,000-m^2 site (see Fig. 8).

Recruitment and Work Qualifications

Hitachi Construction Machinery successfully recruited staff for the factory by advertising widely in Tver Oblast.

Next, workers recruited for tasks such as welding, painting, and assembly were required to obtain qualifications. During recruitment, qualifications were handled using the ETKC vocational qualifications*3 of Russia, which stipulate the skills, knowledge, and level of achievement required for a large number of finely demarcated professions.

However, because companies in Russia tend to have a high degree of demarcation between jobs, many staff did not have all of the expected qualifications at the time of their recruitment.

Accordingly, staff received instruction and sat for examinations at educational institutions prior to commencing operation. Specifically, most of this was done at Konyaeva College*4, a nearby industrial training institution, and Hitachi Construction Machinery donated equipment for use in welding training to establish a collaborative relationship for recruitment, obtaining qualifications, and identifying potential candidates.

To improve the level of knowledge and skills specific to hydraulic excavators, staff underwent training in Japan along with hands-on instruction and competitive assessments at a basic training area set up at the factory.

Features of Production Line and Progress Management

Work performed at the factory includes welding, managing parts, painting, assembly, and inspection. Operations have been set up to use just in time (JIT) production based on the principles of lean manufacturing.

While there is a general awareness of the idea of lean manufacturing in Russia, because there are few examples where it has actually been used, frequent re-education of local staff was needed.

*3 ETKC (Единый тарифно-квалификационный справочник работ и профессий рабочих)
*4 Konyaeva College (Тверской колледж имени А.Н. Коняева)

Fig. 8—Factory Building.
The site includes an office, production facility, and production equipment. It has the capacity to build 2,000 hydraulic excavators a year.

For example, measures were taken to ensure everyone could see the correct situation, such as establishing practices whereby the required parts are produced at the required time to keep a constant level of parts inventory on hand at each step based on process cycle times.

It was also anticipated that problems would arise when production first commenced, such as production delays or a lack of parts at various steps. Accordingly, production schedules were prepared based on theoretical cycle times as worker proficiency steadily improved, and the extent to which these schedules were achieved was assessed on a daily basis using key performance indicators (KPIs) that quantified progress.

Issues that caused poor KPIs were dealt with using the plan, do, check, and act (PDCA) cycle, and quick resolutions were sought at daily progress meetings.

Expanding the Benefits of an "Insider" Status

While medium-sized hydraulic excavators are built to a variety of specifications, the proportion of machines delivered to dealers in the standard configuration was very high in Russia. A factor in this was the difficulty of predicting demand at the time the machines would go on sale, with the long lead time when products were imported from Japan meaning that fitting options at the factory required production to look a long way ahead.

Nevertheless, demand for optional features has been growing in many markets, particularly Japan and Europe, and it was anticipated that this trend would also develop in Russia. Hitachi Construction Machinery's decision to become an "insider" means it can take advantage of its shorter lead times to take steps to satisfy this demand.

Now that the core production equipment and operational framework have been established, a number of specification changes have been made such as changing the width of traction components.

Involvement with Customers and Community

There is a very high level of trust in "made in Japan" in Russia and the CIS. Accordingly, along with becoming an "insider," one of Hitachi Construction Machinery's top priorities was to reassure customers, dealers, and other stakeholders about the high level of quality to assuage their concerns about the increasing proportion of local production and enable them to be confident about purchases. To achieve this, Hitachi Construction Machinery held a ceremony and factory tours in 2014 with a total of approximately 1,000 guests, including customers, dealers, people from regional government and local companies, and educational institutions and their students.

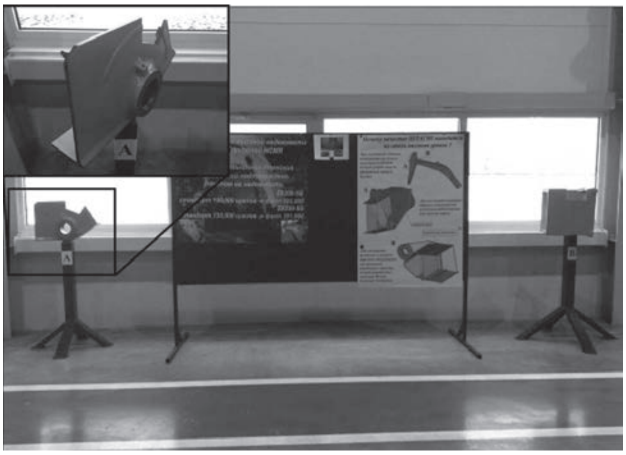

Fig. 9—Presentation of Cutaway Model of Weld at Factory.
Part of the front attachment (a part that requires a high degree of durability) was cut away to provide a visual representation of how well the weld had been performed.

At the same time, Hitachi Construction Machinery also sought to raise understanding through the use of actual products, exhibiting test parts to demonstrate their manufacturing precision and holding product demonstrations. This included a cutaway model of a front attachment weld to provide a visual representation of how the weld reaches the required depth into the metal, something that cannot be seen by external inspection (see Fig. 9).

Meanwhile, Hitachi Construction Machinery also commenced a number of activities that it needed to undertake to become an "insider" and that were aimed at contributing to and becoming part of the local community. One of these was a factory event held in September 2014 that was well received and provided the opportunity to mingle with staff and their families. Hitachi Construction Machinery plans to hold further such exchanges in the future (see Fig. 10).

OVERVIEW OF THE BRAZIL PLANT

Hitachi Construction Machinery decided in 2011 to establish a local manufacturing and sales company in order to become fully involved in the Brazilian market.

Hitachi Construction Machinery and Deere & Company have built an important partnership in North, Central, and South America since the establishment of Deere-Hitachi Construction Machinery in 1988.

Fig. 10—Product Demonstration at Factory Event.
In addition to exhibiting products and giving tours of the facilities, the event included a cultural exchange aimed at meeting staff.

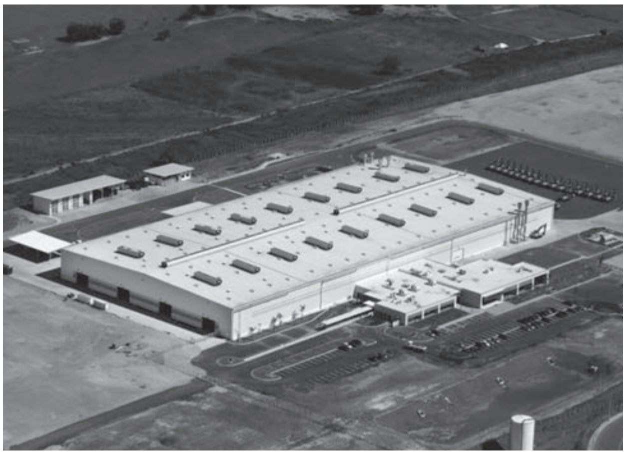

Fig. 11—New Factory in Brazil.
The site includes an office and a plant for the production of medium-sized hydraulic excavators. Most welded structures are produced on site to increase the percentage of locally produced parts.

This included setting up a joint venture company for the manufacture and sale of hydraulic excavators in Brazil to enable the two companies to continue pursuing long-term growth opportunities. Hitachi Construction Machinery contributed the world-class technology from its hydraulic excavators to undertake full-fledged local production, while their presence in Brazil was boosted by having marketing handled by Deere & Company, which has a solid infrastructure in place for agricultural equipment.

Table 1 lists details of the joint venture company and Fig. 11 shows the factory site.

TABLE 1. Profile of Brazilian Joint Venture (Deere-Hitachi Máquinas de Construção do Brasil S.A.)
This joint venture between Deere & Company and Deere-Hitachi Construction Machinery Corporation is located in the São Paulo state of Brazil.

Company name	Deere-Hitachi Máquinas de Construção do Brasil S.A.
Factory	Indaiatuba, São Paulo
Capital	$US130,000,000
Ownership	Hitachi Construction Machinery Co., Ltd.: 40% John Deere Brasil Limitada: 40% Deere-Hitachi Construction Machinery: 20%
Business activities	Manufacture and sales of medium-sized hydraulic excavators (15 to 40 t) Import and sales of mini-excavators and hydraulic excavators (up to 100 t)
Joint venture established	October 2011
Production commenced	September 2013
Production capacity	Approximately 2,000 machines per year (with 60% or more locally produced parts)
Site area	200,000 m^2

Brazil has a Special Agency for Industrial Financing (FINAME) that provides financing assistance to end users when they purchase machinery or other capital equipment. This provides finance on much better terms than otherwise available (lower interest rate and longer term) if the equipment being purchased has 60% or more locally produced parts, making it vital that manufacturers exceed this 60% threshold. The criterion is evaluated by both value and weight, both of which must exceed 60% to be eligible.

Accordingly, Deere-Hitachi Máquinas de Construção do Brasil S.A. produces most of the heavy welded structures itself. The following measures were adopted to commission the production of a wide variety of welded structures in a short period of time.

(1) Production equipment and processes were based on those at Deere-Hitachi Construction Machinery in the USA. Staff from Deere-Hitachi Construction Machinery were sent to Brazil to assist with commissioning the equipment, while production engineers and other staff from Brazil were sent to Deere-Hitachi Construction Machinery for training lasting from several weeks to several months.

(2) A major help with welding skills came from Deere-Hitachi Máquinas de Construção do Brasil's recruitment of nine Brazilian technicians who had been working for Hitachi Construction Machinery. In addition to welding skills themselves, the technicians were able to pass on Hitachi Construction Machinery's approach to things such as manufacturing and quality to the worksite, so the plant was able to achieve a very high level of technical skill for a new operation.

CONCLUSIONS

This article has described the history of the expansion of overseas production undertaken by Hitachi Construction Machinery Co., Ltd. in accordance with its production strategy, together with the features of the plants it recently opened in Russia and Brazil.

Local production for local consumption is at the core of Hitachi Construction Machinery's production strategy. In addition to contributing to regional economies by delivering products to customers around the world in a timely manner, this provides commercial benefits in the form of driving further cost savings and reducing exchange rate risk. What will also be needed in the future is to acquire the operational flexibility to enable product supply accommodations to be arranged between regions. This is to adapt to fluctuating regional demand and to avoid missed opportunities with the aim of maximizing consolidated marginal income by making strategic use of production sites.

REFERENCES

(1) R. Seguchi, "'Kono Ki Nanno Ki' (What tree is this?): A Half-century with Hitachi Construction Machinery," Hitachi Intermedix Co., Ltd. (Apr. 2008) in Japanese.

(2) R. Seguchi, "Management Reforms at Hitachi Construction Machinery," Corporate Communications Division, Hitachi Construction Machinery Co., Ltd. (Sep. 2005) in Japanese.

(3) H. Kitawaki et al., "Progress of European Business and Commissioning of Amsterdam Plant," Summary Report, Hitachi Construction Machinery Co., Ltd. (Jan. 2014) in Japanese.

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Topics

Advanced Technologies from Hitachi for a Changing Mining Business

AUTONOMOUS HAULAGE SYSTEM TRIALS OF DUMP TRUCKS IN AUSTRALIA

The mining industry in the past has been characterized by rising production volumes based on a background of strong demand for mineral resources from emerging economies. With the slump in commodity prices since the widespread economic recession triggered by the 2008 global financial crisis, however, the focus of mining company businesses has been undergoing a major shift toward improving things like productivity and safety.

Making use of data and other information in operations is important for improving productivity and efficiency. Wenco International Mining Systems Ltd., a subsidiary of Hitachi Construction Machinery Co., Ltd., supplies a fleet management system (FMS) that collects and analyzes data from excavators and dump trucks used at mines, and is used by vehicle dispatchers to issue instructions and other information to drivers (for more information, see the article on p. 20 of this issue).

Because the typical practice at a mine is for each excavator to work in conjunction with a number of dump trucks, improving mine productivity requires that these vehicles be operated more efficiently. To achieve this, Hitachi is also working on the development of its autonomous haulage system (AHS) for dump trucks, which improves safety and reduces operating costs. A current challenge is how to operate a number of dump trucks within the same area. The know-how built up by Wenco is crucial to identifying safe and efficient ways of operating at mines where large numbers of vehicles, not just dump trucks, are moving around the site.

An AHS demonstration project underway in Australia consists of trials involving both real and virtual dump trucks. This approach was adopted to minimize the cost and time of the trial and to reduce the risk of vehicle breakdowns, and also to make development more efficient by using simulations of virtual machinery. The information and communication technology (ICT) of the companies in the Hitachi Group is utilized in the development of this advanced technology.

Demonstration project for autonomous haulage dump-trucks underway at a mine in Australia

ACHIEVING IDEAL MINE OPERATIONS THROUGH PIT TO PORT OPTIMIZATION

Whereas the scope of FMSs in the past has been restricted to individual mines, the migration of its FMS to the cloud is a field where Hitachi's comprehensive capabilities ("One Hitachi") can be put to good use. While this brings new technical challenges such as ensuring reliable information security and reducing the communication delays that are a function of physical distance, it is also a business where Hitachi can deploy the ICT it has built up through its work on building infrastructure systems. Migrating the FMS to the cloud will enable remote dispatching, meaning that managing and issuing instructions for vehicle dispatch at distant mine sites can be handled from an urban command center. Furthermore, analyzing data from a number of mines should help identify potential solutions that would not be evident from the information obtained from a single site. Hitachi recognizes the mining industry as a key field for the application of big data.

As well as being a site for the operation of large machinery such as excavators and dump trucks, a mine also consumes a lot of water, energy, and other resources. In recent years, mining companies have been showing a growing interest in "pit to port" optimization involving all of the processes from excavation to processing, transportation, and loading at the port. With its extensive know-how in social infrastructure that includes ICT, plant, water treatment, power generation, and railway systems, Hitachi has the potential to deliver promising solutions for ideal mine operations.

REFERENCES

(1) "Hitachi Construction Machinery's Dynamic Solution is Set to Change Mine Management—What is 'MICT'?," Tierra+, No. 112, pp. 3–9 (Mar. 2015) in Japanese.

(2) "A Stage for Collaborative Creation for Big Data Utilization as it Spreads Worldwide," Realitas 12, pp. 28–33 (Mar. 2015) in Japanese.