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HITACHI GROUP The Power of Collaboration

Hitachi Construction Machinery Group

HITACHI GROUP The Power of Collaboration

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Target Gross Machine Operating Weight: 500 tonnes;
Nominal Payload with Standard Equipment: 296 tonnes.
The EH5000AC-3 is the largest and most sophisticated rigid dump truck from Hitachi Construction Machinery (HCM).
It incorporates a series of advanced technologies adopted from various Hitachi Group Companies.
Developed in collaboration with Hitachi Ltd., one of the world's largest electrical product manufacturers, the Hitachi AC Drive technology delivers unparalleled performance supporting higher truck availability, improved gradeability and increased travel speeds.
This technology has been refined through the Shinkansen bullet trains and other major infrastructure projects.
More than that, it is the power of Hitachi's technology collaboration that allows this development to be completed with such a short lead time.

EH5000 AC-3

Hitachi's EH5000AC-3 is packed with industry-leading technologies

The Hitachi EH3500ACII and EH4000 ACII incorporate the AC Drive system, powered by Hitachi-manufactured IGBT inverters. These rigid dump trucks were co-developed with other companies in the Hitachi Group and have been delivered to mining sites all over the world.

Compared to a mechanically driven system or a DC-driven electric system, the AC-driven electric system has a larger brake capacity. This capability is due to the independent control of the motors on both sides. This system has a simpler structure with fewer parts that results in reduced maintenance costs. With these strong advantages, HCM has manufactured the EH3500ACII and EH4000ACII with a highly efficient AC wheel motor that provides significant driving power and braking force. It's the very first case in this field that an AC-drive System was manufactured internally. This remarkable achievement was possible because of the power of technology collaboration by Hitachi.

The recently launched EH5000AC-3 demonstrates a new level of sophistication through the "Power of Collaboration".

Takayuki Sato of the Technical Research Center of HCM, a coordinator of the loading technologies during the development, says, "It's a high technology AC-driven dump truck that has been created by a combination of the cutting edge technologies and engineering spirit of Hitachi Group. This product became possible because we are Hitachi Group."

Youhei Nakate of HCM's Development Center,Mining & Heavy Equipment Division took charge of the design to integrate the loading technologies. Nakate is proud to say that "We integrated as many of Hitachi's advanced technologies as were available today."

Major features of the EH5000AC-3 include the new Hitachi drive control system referred to as "Body Stability Control". This system made detailed speed and torque control possible with the new software developed by the total power of the Hitachi Group companies, starting with Hitachi,Ltd. The sensors installed at each section detect variables such as the angle of steering or the difference in the torques of the rear wheels on both sides and then analyzes the differences to determine the operating conditions such as a locked tire. The system then instantly controls the independent motors installed on both rear wheels to deliver a stable traveling condition. This system also controls problems such as slipping, tires being locked, and movements forward and backward when the brake is applied, and even sliding during cornering.

We can say that it is Hitachi's technology, refined through the continual and long-term development of the electric control system and motors, that made these advancements in traveling control possible.

Improvements in operability can result not only in reducing the operator's burden but also with lowering the customer's maintenance cost. This is because with a lighter load, the body and the parts of the truck last longer and the number of problems is reduced.

"For example, this system reduces the friction of the tires. Since the tires for mining are very expensive, this reduces the cost." speaks Sato at the Technical Research Center.

"SkyAngle" (to be described later) displays the area around the body of the truck from an angle that looks down from the sky. This new technology increases the truck's safety and was co-developed by Clarion of Hitachi Group Company. This is the very first technology of its type for an rigid dump truck.

Also, the pantograph (a thing which takes electric power from an electric power line above it), designed for trolley-type of the EH3500ACII and EH4000AC II was developed in a technology collaboration with Hitachi Power Solutions.

In overseas mines, there are some examples of trolley-type dump trucks with a pantograph that operate under dedicated overhead wiring to improve the mobility of the dump trucks. In order to obtain electricity safely, it's crucial to consider matching the overhead equipment along with the components and the manufacturing method. In the development of this technology, the infrastructure sector of Hitachi is involved.

Ryuichi Nakazawa of Hitachi Power Solutions, who took charge of the pantograph development, shows his confidence. "Although it was our very first attempt to develop a pantograph, we could create the pantograph filled with the technologies and know-how of the Hitachi Group. It has such high quality that we can proudly introduce it to the world." Hitachi Power Solutions was in charge of the materials and structural analysis. Nakazawa also says, "We kept improving the quality by 'compensating numeric separation' through vibration tests and the prototype tests conducted by HCM."

HITACHI GROUP The Power of Collaboration

EH5000 AC-3

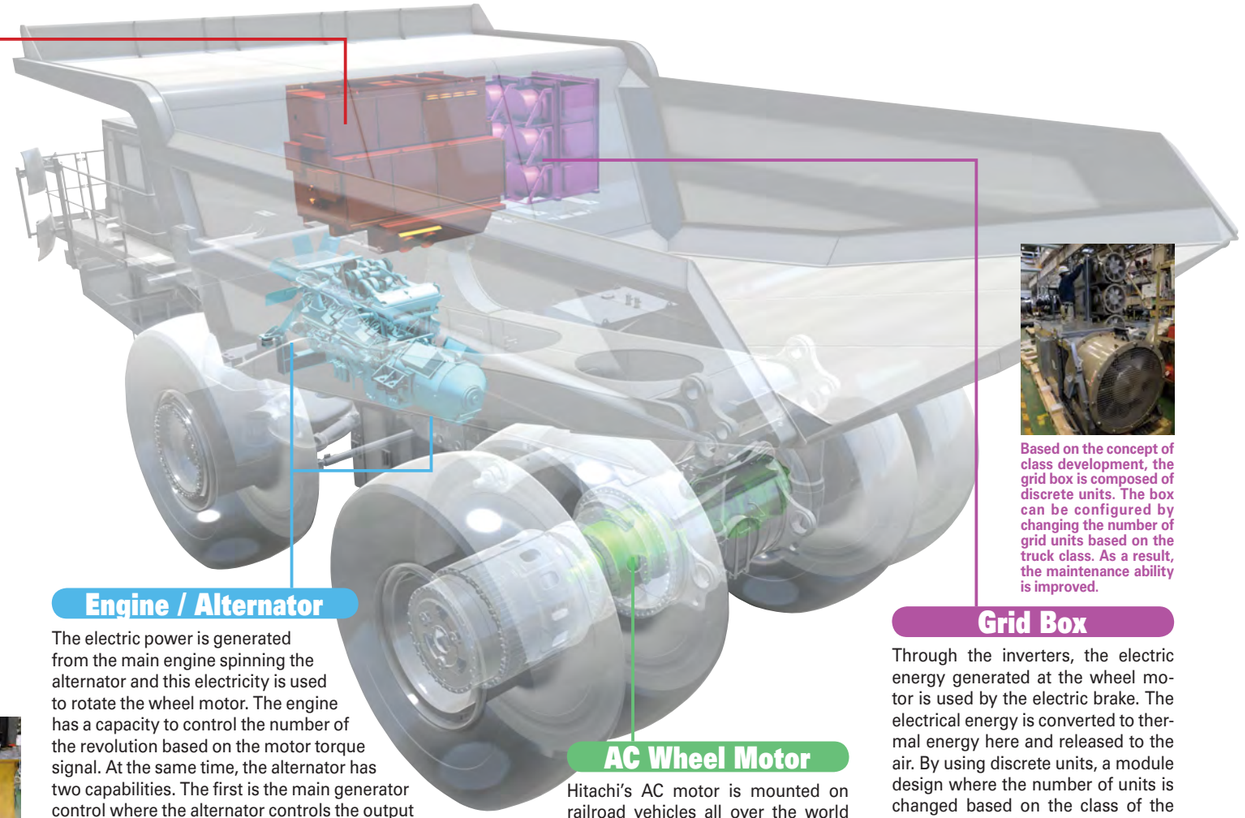
The next generation AC Drive Rigid Dump Truck, innovated by Hitachi's technology collaboration, is directed toward the "smart mining era".

Control Cabinet

The control cabinet of EH5000AC-3 installed near the operator cab. It's the component that is the main drive system of AC.

The central part of the AC-drive system where the IGBT inverters, the body stability control system, and other elements are located. The AC method is to convert alternating current from the alternator to direct current and then control the current in the inverter to convert it back to alternating current to feed to the AC wheel motors. The inverter is equipped with an "IGBT inverter" that has been continually improved since its adoption in the 700 series Shinkansen in 1997. The IGBT inverter is excellent in switching performance and is capable of very accurate control of the motor's speed of revolution and its torque. It was also low cost, space-saving, and a reduction in weight. It's a culmination of all Hitachi's technologies.

Left : Alternators generate electricity from the power of the engine.
Right : The engine and the alternator are attached to the main frame.



Engine / Alternator

The electric power is generated from the main engine spinning the alternator and this electricity is used to rotate the wheel motor. The engine has a capacity to control the number of the revolution based on the motor torque signal. At the same time, the alternator has two capabilities. The first is the main generator control where the alternator controls the output voltage based on the speed of revolution of the engine, the speed of the body, and the torque signal of the motor. The other is the supporting generator control which controls the output voltage despite of the number of revolution of the engine.

AC Wheel Motor

Hitachi's AC motor is mounted on railroad vehicles all over the world including the Shinkansen in Japan, as well as in Australia, in Thailand, in Brazil, in Indonesia and so on.The same technologies are used in the wheel motor of the EH5000AC-3.

Based on the concept of class development, the grid box is composed of discrete units. The box can be configured by changing the number of grid units based on the truck class. As a result, the maintenance ability is improved.

Grid Box

Through the inverters, the electric energy generated at the wheel motor is used by the electric brake. The electrical energy is converted to thermal energy here and released to the air. By using discrete units, a module design where the number of units is changed based on the class of the dump truck can be applied.

From left : 1) Hitachi's AC motor that has been refined by the Shinkansen project. 2) being joined with a speed reduction gear and a braking system. 3) being installed at the rear spindle where the electric cables of the sensor and the driving control are attached. 4) the inside view after the installation

Technology collaboration has greatly accelerated our production development.

The sharing and standardisation of parts have also improved through technology collaboration. The EH3500ACII, EH4000ACII and EH5000AC-3 are equipped with different output of wheel motors. However the wheel motors are interchangeable with one another.

For example, by matching the size, the motor for the EH5000 can be mounted on the EH4000 that has a trolley design. This interchangeability substitute for reducing both supply chain distance and machine down time.

Katsuhiko Fujii of Hitachi Power Systems Company took charge of the development of the wheel motor. He says, "Standardization on the sizes of the parts can lead to cost reduction and extensibility in the future. Since they are different sizes by nature, it was a tough challenge, but we wanted to meet the demands regardless."

"Product layout" means how to place the parts and materials in the product. Nakate, who designs the bodies, says "Standardization of the sizes made the product layout easier and helped us a great deal to design smartly." He could feel the real impact of the technology collaboration. All you have to do to change the module design is to change the number of units in the grid box.

These types of ideas among the engineers increased the development speed.

HITACHI GROUP

The Power of Collaboration

EH5000 AC-3

"A quick response is how I would summarize this," Nakate describes. "During the development of the EH5000AC-3, no matter what approaches or ideas we came up with, there were always so many problems we had to solve. For example, after completing the prototype, we were considering installing a new part to improve a function. We had to determine the installation location of the part and the noise interference against the equipment. The involved people from the various Hitachi Group companies were able to gather right away to have an open technical discussion and to review the layout of the equipment. We couldn't have done this if we were not one group."

Kazuhiro Enomoto of Hitachi Infrastructure Systems Company who took charge of the AC-drive control also talks about the merit of the technology collaboration.

"When you work individually, each company, each department has its own strength and weakness. However, by communicating or collaborating with others, you can get ideas and opinions that can resolve any weakness. Also, the fact that most of the Group companies are located in the Ibaraki prefecture area was a great advantage. We were able to say 'E-mail is not enough. Let's meet and discuss!'"

Nakate explains with the following episode.

"In the development stage, some issues always happen. Once, three EH5000AC-3 machines that were undergoing testing at the Urahoro Test Site in Hokkaido were damaged. After our message to the Hitachi office, a staff member was sent by the last flight of the day and he started checking the machines at midnight right after his arrival. It turned out we had to replace the high tension cable and when we requested a new cable for the trucks, they managed to replace them the following day. I realized that it was the technology collaboration of the group that was driving the development of these dump trucks."

On the other hand, Enomoto, who was the one who flew to the site, talks calmy.

"All along, we, Hitachi Infrastructure Systems Company, have been dealing with industries such as railroads and electric utilities that have a huge impact to society. So our mind is set on fixing any problem as fast as possible. Rushing to the site is fundamental for us. Since this case was internal to the group and the technical information was instantly available, we could respond quickly."

We also faced an "Ultra C" (i.e. "extreme difficulty") that shouldn't be faced in normal development.

In a normal development process of new technology, a prototype that is expected to go to production is built and tested. However, in this case, there were some technologies that were added after the prototype was already completed. Therefore, we had to remodel the body of the prototype. One of the examples is Sky Angle. Nakate, the designer of the body, says, "There were problems that we found after we installed the Sky Angle to the body. We had a tough time meeting the production schedule of EH5000AC-3."

Yoichi Kowatari of the Control System Center, in charge of the Sky Angle, expresses the thoughts of an engineer.

"If the technology is already ready, we would like to install it. If we miss the chance for mounting it to the body, then we would have to wait for a few years for the next model change. We would prefer to avoid that delay. I have to say that this time we were able to install it after the completion of the prototype simply because of the power of our technology collaboration."

The manufacturing site of the rigid dump trucks is at Hitachinaka Rinko Works in Ibaraki prefecture.

Working together as a group makes information sharing and experimental equipment tests possible.

Hidefumi Ishimoto, of the HCM Technical Center says, "No other companies can duplicate either our speed of development or the way we crafted EH5000AC-3 as a product."

Functions such as the body stability control technology require detailed control of the hardware. Therefore, how much technical information is shared among the members of the project is really critical to the precision of the software design.

Katsuhiko Fujii of Hitachi Power Systems Company says, "The information was released at a level that normally isn't done. By doing so, we were able to discuss the information in detail and that impacted the design."

Also, Yoshikazu Tokairin, a engineer of Hitachi Infrastructure Systems Company, who is in charge of the software development of the body control, says, "in terms of design, it's a huge advantage of the technology collaboration that the newly developed technology can be mounted to a real machine and checked right away."

"In companies outside Hitachi Group's case, when some new control is to be mounted onto a machine, it's not easy to test on a real machine because of the information management issue. If we can test right away, that's a huge advantage. As a matter of fact, we were able to find out so much by doing this."

Norio Ueda of Hitachi Power Solutions, who worked on the materials and structural analysis, thinks highly of the information released in the internal Hitachi Group collaboration which is not available in collaborations outside the group.

"In order to understand the durability of the products precisely, the analyzed data and the test results have to be agree closely. This time, the test results agreed with the lifespan of the analysis. I'm sure that it's because a detailed draft was released within the group. For those of us who are working to build an analysis center for the entire Hitachi Group, this technology collaboration was a great experience."

During this development effort, two companies were involved with the drive control system development. Akira Kikuchi of Hitachi Research Laboratory believes that the strength of each company in the collaboration was reinforced.

Kikuchi also says, "HCM knows how dump trucks should run from the body perspective. Hitachi Research Laboratory knows how to control the sensors. By developing what each company is skilled at, each company's strength is reinforced. Furthermore, our strength is that we can integrate the technology and information of the entire group at a higher level by sharing the technology and information that each company has.

We are always adjusting the roadmap of the research items with HCM and we are playing a role in the information management of the group, with Hitachi Research Laboratory as a hub. I predict that collaborations like this will continue to increase from now on."

Body Stability Control System

This system gathers information from every sensor, lever, and pedal in the drive system control. It processes and analyzes the data, and then sends a drive instruction through the inverter to the individual motors on the left and right side. This same approach is used to send a control instruction to the electric brake. With this system, the stability of the body is improved, along with the truck's productivity and safety.

※front wheel speed sensor / wheel motor speed sensor / steering angle sensor / suspension pressure sensor / combined sensor (forward and backward direction acceleration sensor・left and right direction acceleration sensor・turning angle speed sensor) etc.

Slip/Slide Control System

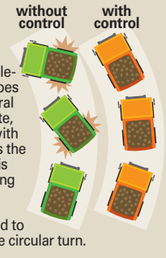
The controls bring a stable acceleration and deceleration by smoothing the body movements. They enhance the responsiveness by sensing the racing or locking of the rear tires and then adjusting the torque of the wheel motor during acceleration and deceleration on slippery and bumpy roads.

Pitch Control System

When the system senses pitching while traveling over bumps on a road or on a climbing hill, the torque of the wheel motor is adjusted to reduce the pitching of the body and to smooth the ride. At the same time, load spills can be prevented.

Side Skid Control System

The system calculates the level of stability of the body that is created by the operation of the steering wheel, the accelerator, and the brake. It does it by monitoring the lateral acceleration, the yaw rate, and the steering angle with sensors. Then it controls the side sliding as the truck is making a turn by adjusting the torque of the wheel motor to make the body movement smoother and to implement a more stable circular turn.

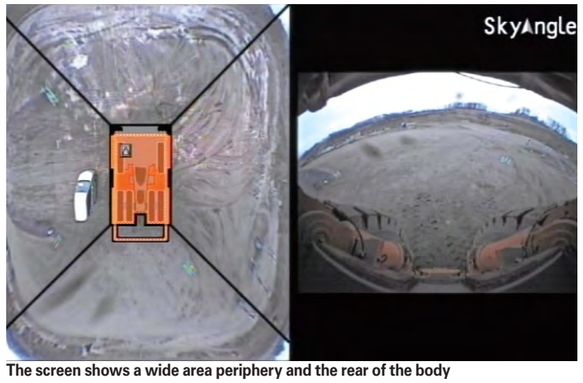


HITACHI GROUP The Power of Collaboration

SkyAngle

The cameras are mounted at four spots: at the front, the left side, the right side, and the rear. The images of the four cameras are interchanged and synthesized to show the area around the machine on the monitor near the driver's seat in real time.

The task of adapting the technology from passenger vehicles to very large dump trucks.



The screen shows a wide area periphery and the rear of the body

From top: The screen shows a wide area body periphery, an intermediate area body periphery, and a nearby body periphery.

The SkyAngle technology far exceeds customer expectations.

"SkyAngle", a device designed to enhance safety by monitoring the vehicle's surroundings. It is available as an option in the EH5000AC-3, and was developed via the collaboration with the Hitachi Group company, Clarion.

The base technology has already been mounted on a number of passenger vehicles and released into the market.

Keiji Sato of Clarion, who was in charge of the development, says "First, I was thinking that the remaining task was only how to install it on the body."

Yet, it wasn't as simple as he imagined. First of all, there was a huge disparity in the sizes of the vehicles.

"In the case of a passenger vehicle, an image that is only two meters in circumference is enough. However, if the body of the vehicle is larger, it has to be able to see further. In addition, an object in the distance has to be seen in three-dimensions." speaks Keiji Sato.

At the beginning of development, Ishimoto also realized how large the task was.

"The four images are synthesized together. But the body is so large that if the angle of any camera moves slightly out of the position, the whole image is disjointed. Also, dump trucks become warped as they are used over years. In order to introduce this to the market, we had to consider a system to support regular adjustments of the cameras."

On other side, Kowatari, who was in charge of the SkyAngle production process says "Our desire just kept growing."

"During the work at mining sites, the dump trucks are surrounded by moving service cars and ground-leveling vehicles. Unlike passenger vehicles, it's hard for the operator to recognize the surroundings of the body with the naked eye. So sometimes minor collisions and scrapes do happen. There have always been requests for a solution to this problem from our customers. Although Sky Angle received high praise from the beginning of development, mounting the same technology used in the passenger was the first step; and during development, we started receiving many requests such as making it easier to recognize the surroundings of the body at the first glance, and to see not only the image around the body but also underneath the body as well."

Keiji Sato also says, "As testing proceeded on the prototype, we repeatedly made changes and adjustments. We developed technology that is not included in the passenger vehicles' SkyAngle."

As a result, with a stronger camera and higher concussion resistance, the team created a SkyAngle that is durable enough to survive the harshest mine sites. The visibility of SkyAngle was improved to see objects in the far distance, unlike the one used in the passenger vehicle.

Kowatari confidently says. " The safety level of the truck has been improved remarkably. Until now, the surroundings check was done using six mirrors at the front and rear and by viewing the images taken by the two rear side cameras on a monitor but now with SkyAngle, all you have to do to check the surroundings is to look at one monitor. There is no doubt that this will reduce the burden on the operator dramatically."

Nakate who changed the design to mount the SkyAngle to the body after the prototype was completed says, "Because multiple companies were involved, many ideas were considered, and this resulted in the confidence to mount this cutting-edge technology quickly.

With the development for the current EH5000AC-3, Takayuki Sato of the Technical Research Center has high expectations for the potential technology and the power of collaboration work to increase the speed of development.

"Hitachi group still has so many more useful technologies to use, including a rail transit management system, rolling stock technologies, robot technologies, car navigation technologies and so forth. With a combination of these advantages, some development that would normally take 20 years by the competitors can take us only five years to complete. In the future, we want to exert our power of the Hitachi group collaboration work into the unmanned operation of the dump truck by the use of automatically traveling and, ultimately, in the total management of mining. In other words, we want to implement "smart mining."

We are Collaborators!!

Hitachi,Ltd.
Hitachi Research Laboratory
Senior Researcher
TD3Unit,Department of Transmission & Systems Research

Akira Kikuchi

Took charge of the entire AC drive system control, and the slip and slide control.

" Eventually, we want to capture the entire mining process as an infrastructure system and share that with Hitachi Group."

Hitachi,Ltd.
Power Systems Company
Senior Engineer
Electrical Machinery System and Plant Construction Engineering Department

Katsuhiko Fujii

Took charge of the AC wheel motor develpment.

"Scoping the future development, we standardized the large-sized electric parts and enhanced their interchangeability. This seems to be standard but it should provide a benefit to our customers."

Hitachi,Ltd.
Infrastructure Systems Company
Engineer
Control Systems Quality Assurance Department

Kazuhiro Enomoto

Took charge of the development of the drive system control.

" High-powered electical technology is also our competitive advantage. This collaboration work convinced me that we could create a basis to receive a package order, including the trolley construction. "

Hitachi,Ltd.
Infrastructure Systems Company
Engineer
Power Electronics Design Department

Yoshikazu Tokairin

Took charge of the design of AC wheel motor control.

" The saying ' Machines don't lie', which I learned in the analysis of a real machine, is still alive in my mind. I learned so many different meanings of that phrase."

Hitachi Power Solutions Co.,Ltd.
Senior Engineer
Substation Systems Solution Department

Ryuichi Nakazawa

Took charge of the pantograph.

" Because we, as a maintenance company, were able to create a pantograph that is maintenance-oriented."

Hitachi Power Solutions Co.,Ltd.
Manager
Analysis Engineering Department

Norio Ueda

Took charge of the structural analysis of the pantograph and of the analysis of its various parts, such as bearings.

" The fact that we could improve our critical analysis gave us confidence. From now on, I'd like to improve the technology level as the Analysis Center of Hitachi Group."

Clarion Co.,Ltd.
Manager
Camera System Management Department

Keiji Sato

Took charge of SkyAngle development.

"Although this was the very first collaboration work with Hitachi Machinery, we could create an extremely high quality product. We'd like to adopt this to vehicles such as buses and commercial trucks."

Hitachi Construction Machinery Co.,Ltd
Senior Researcher
Technical Research Center

Takayuki Sato

The coordinator for mounted technologies.

" Further analysis of the data about the dump trucks and excavators that are operating all over the world must make Hitachi Group capable of doing so much more."

Hitachi Construction Machinery Co.,Ltd
Engineer
Development Center
Mining & Heavy Equipment Division

Yohei Nakate

Took charge of designing for the Model 3 dump truck body.

" By having Hitachi group companies involved, we gained many options as possible solutions to the problems. It also led to a reduction in time and money."

Hitachi Construction Machinery Co.,Ltd
Senior Engineer
Control System Center

Yoichi Kowatari

Took charge of the mass production of SkyAngle.

" Our strength is to be able to mount the technologies developed by Hitachi group companies to a real machine. Because of the quick feedback, the development speed was improved."

Hitachi Construction Machinery Co.,Ltd
Senior Researcher
Technical Research Center

Hidefumi Ishimoto

Took charge of the safety technology development though the use of cameras.

" The level of the productionalization implemented was higher than expected. We are eager to establish autonomous traveling by using the power of the group."

HITACHI GROUP
The Power of Collaboration

Hitachi Construction Machinery

Hitachi Power Solutions

ASTACO-SoRa

A double-arm robot created by the combined intellect of the two companies; hoping to use in the recovery of the area involved in the nuclear power accident.

A beautiful sky for Fukushima again – the double-arm robot "ASTACO-SoRa" was named after such hope. (ASTACO stands for Advanced System with Double Arms for Complex Operation. 'Sora' means sky in Japanese.)

This double-arm robot has been developed under a plan to use it at the Tokyo Electric Power Company Fukushima I Nuclear Power Plant. The robot was created by the collaboration between Hitachi Power Solutions and Hitachi Construction Machinery (HCM).

Hitachi Power Solutions has a diverse range of business interests. Among them, the contract for the maintenance of nuclear power plants. Some of the routine maintenance work such as replacing components inside the pressure vessels is undertaken in the presence of radiation. Therefore, in order to handle such maintenance works properly, Hitachi Power Solutions developed its own robotic tools and has been building an extensive amount of real-world experience in tasks such as grabbing, pulling up, and disconnecting by remote control.

Takashi Sekigami at Hitachi Power Solutions says," Because of that expertise, we have been considering whether we can contribute in some way to the area's recovery from the accident. At the same time, it became a directive from the company."

As the investigation proceeded after the accident, we began in earnest to see the detailed road map required to decommission the nuclear reactors. By considering that objective, we determined our own product completion date and began to analyze the machinery and materials required.

Hitachi Power Solutions draw the machinery and materials that match the specifications of the work and there was a need for a robot with multiple working arms to be operated by remote control. This had to be implemented within a very limited time frame. Hitachi Power Solutions selected HCM as its partner for the development of the robot.

Hitachi Power Solutions Co.,Ltd.
Assistant to Division Manager
Power & Industrial Systems Division
Takashi Sekigami

Initial discussions of a joint collaboration between both companies occurred in September 2011. Immediately after confirming the details with the people involved, an agreement was reached. By October, the engineers from both sides had an initial meeting and the joint development project took off with exceptional speed in November.

Eiji Egawa of HCM, responsible for strategy planning of new products such as the double-arm robot, said;

"It was a decisive battle within a short period that usually does not happen. It was challenging but we understood its significance, as it's something not just for Fukushima but also for the recovery of the entire nation from the disaster. It is something that we cannot avoid."

The specifications required for the ASTACO–SoRa came from the engineering know-how that Hitachi Power Solutions had obtained through its maintenance work at the plant. The needs include a grip force, the configuration of the attachment, the locations of the cameras and sensors, and so forth.

Since remote control is fundamental to the product, the information and communication expert unit from Hitachi Power Solutions joined the Plant Headquarters as reinforcements. Responding to their requests, HCM continued to design the body structure of the base machine with their own expert unit.

However, it's impossible to design a body in a day. In the beginning, there was even a gap between the expectations of the two parties. After visualising how industrial robots should operate, Hitachi Power Solutions considered the ideal robot to feature separate arms that move like that of human arms. In contrast, HCM knew very well the physical limits; having double arms only makes the conditions more complicated. They had to consider how to make the hydro hose and the angle of the link reach their physical limit, as well as how to balance the engine power and the grip force. There were things that were possible and things that were not possible. There were things that could be implemented by the completion date and things that could not be implemented by the completion date. "We want the sensor here." "That spot will be filled with other parts and there will be no space available." "We want to change the location of the camera." "Although it will end up with a major change to the basic structural layout, we'll try it anyway".

Within the tight constraints, the engineers shared their know-how with one another by having open and frank discussions. Although sometimes there were heated arguments, they had the shared goal to create a useful work robot for the site. They kept working to find the best solutions.

Sekigami says, "By repeating discussions based on each others' drafts and by redoing the drafts, we kept strengthening the basic design. We had frequent meetings until we finally decided the basic specifications."

Egawa goes on, "We were all engineers in our specialized fields. Therefore we all understood the difficulty of the implementation and how great each others' desire was to make it real. That was the place where we could find the best solutions."

At the last spurt, when the assembling of the real machine took place at the headquarters of Hitachi Construction Machinery Japan (Soka City in Saitama Prefecture), the staff from Hitachi Power Solutions joined the work, staying overnight. They assembled the various units such as the control system components together.

This is how the first year proceeded after the kickoff of the project. Including the discussions for the specifications, the ASTACO–SoRa was completed in a record short period of time and was officially released to the press in December, 2012.

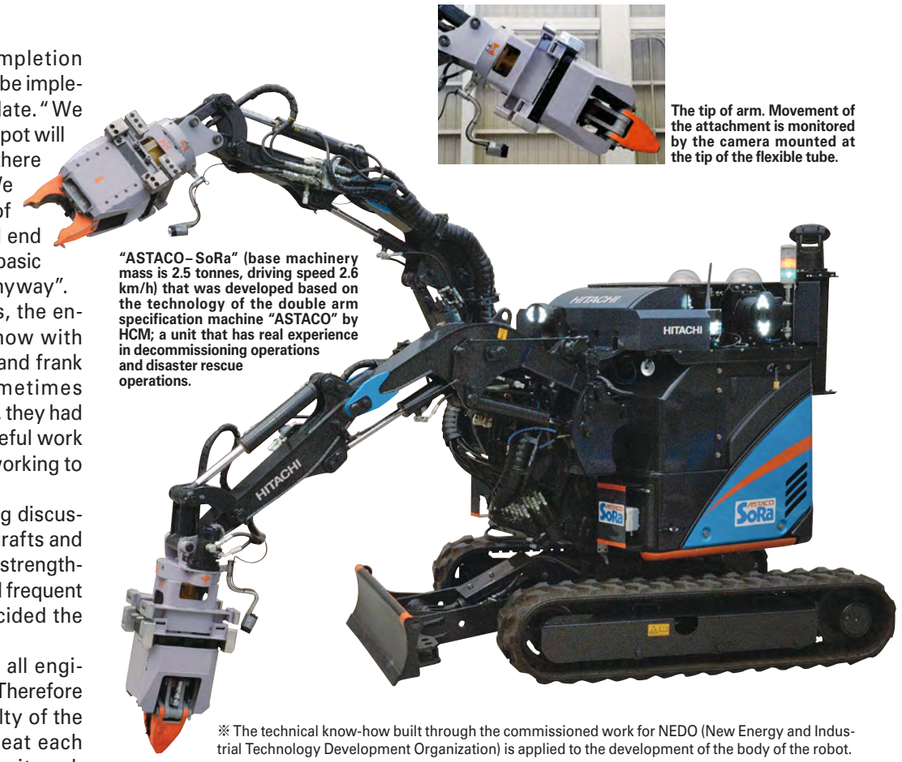
The Hitachi Zaxis 17U mini excavator is the base machine. It's a double-arm robot with identical arms on both the left and right. The maximum transportable mass is 150kg per arm. In order to handle the complex work inside the Fukushima nuclear power plant, a cutter, grapple and a driver drill are required. These attachments will be utilised in the removal of rubble, carrying machinery and materials, building a structure that blocks radiation to protect workers, as well as securing a workspace. Also, an expansion and contraction-type long arm equipped with a camera and a dosimeter for investigations of high areas was prepared.

During a remote operation, both the site situation and the work situation are monitored through six cameras using light-emitting diodes. Besides the microphone that convey the sound situation and the laser system that measures the vehicle width and distance supplemented the remote operation effectively.

Training for the operators was held in a simplified environment that replicates the buildings of the power plant and the robotic movements required. The robot started rubble removal in July 2013.

Through this joint development, Sekigami of Hitachi Power Solutions has the following thoughts.

"In the beginning, I was concerned if we could discuss what we really thought. But gradually, as engineers, we started to fit with one another's vector. At the end, I believe that all of us were united by a strong desire to create a good thing together as Hitachi Group."



The tip of arm. Movement of the attachment is monitored by the camera mounted at the tip of the flexible tube.

"ASTACO–SoRa" (base machinery mass is 2.5 tonnes, driving speed 2.6 km/h) that was developed based on the technology of the double arm specification machine "ASTACO" by HCM; a unit that has real experience in decommissioning operations and disaster rescue operations.

※ The technical know-how built through the commissioned work for NEDO (New Energy and Industrial Technology Development Organization) is applied to the development of the body of the robot.

A camera with an LED to look forward, a microphone for voice, a distance-estimating laser, and a light source and detector are mounted at the front of the body. Left; A work simulation with a cutter installed on the right arm, practicing tasks such as cutting off railings and laying pipes.

A camera with an LED that rotates 360 degrees is mounted on the both the right and left sides. It's able to monitor everywhere including forward, backward, below the legs, and above the unit. A data transmitter-receiver using 2.4 GHz to handle the image transmission is located in the transparent dome.

Left; Laser equipment is used to measure vehicle widths to judge whether the vehicle can enter narrow spaces. Right; Since the width of the crawler is expandable and contractible, it can become compact. The camera with the LED mounted at the rear moves upward and downward as well. It can monitor forward and backward by rotating.

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A performance test under the expected conditions at the site. The wireless connection is approximately 50 meters away and is connected externally using optical fiber cable. This is a system to connect the control board to the receiver that is operated within range nearby.

The control board that remotely controls the ASTACO–SoRa with four levers and various buttons. Operator interacts with five screens to monitor the situation.

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