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.
**Hitachi’s EH5000AC-3 is packed with industry-leading technologies**

The Hitachi EH3500ACII and EH4000ACII 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 result 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.”

**Youhei Nakate of HCM's Development Group**

Youhei Nakate of HCM's Development Group 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 EH4000ACII 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.

**Ryuzi Nakazawa of Hitachi Power Solutions**

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.”
The sharing and standardisation of parts have also improved through technological collaboration. The EH5000ACI, EH4000ACI 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 onto the EH4000 that has a trolley design. This interchangeability substitute for reducing both supply chain distance and machine downtime. Katsuhiko Fuji 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.

“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, to test it on real machinery, 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.”

Kazuhito Emoto 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 weaknesses. 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 ‘Terry 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 under 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, Emoto, who was the one who flew to the site, talks calmly. “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 remold 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.”

Yoshihiko Kawatari 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.”

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The manufacturing site of the rigid dump trucks is at Hitachi Ltd’s Hidaka Works in Ibaraki prefecture.

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

Hidetumi 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 Tokairi, an 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 reliable.”

“In companies outside Hitachi Group’s case, when some new control is to be mounted onto a machine, it’s not easy to test it 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 Udai 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 analys. I’m sure that it’s because a detailed draft was released early. For those of us who are working to build an analysis center for the entire Hitachi Group, this group-wide 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.”

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.”
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.

"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 huge disparity in the sizes of the vehicle.

"In the case of a passenger vehicle, an image that is only two meters in circumference is more. However, if the size 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 addition, an object in the distance has to be seen in three-dimensions," says Keiji Sato.

On other side, Kowatari, who was in charge of the SkyAngle simulation 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 SkyAngle received high praise from the beginning, 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, robots, navigation technologies and so forth. With a combination of these advantages, some development that would normally take 10 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."
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. IASTACO 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 commission 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 draws 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. Initial discussions on the 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 requirements included a gripper, the configuration of the attachment, the locations of the cameras and sensors, and so forth. The remote control panel was 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 its 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 this robot to feature separate arm axes 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 limits, as well as how to balance the engine power and the gripper 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. Some of the things needed were “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 other’s’ desire was to make it real. That was the place where we could find the best solutions.”

At the last spur, when the assembling of the real machine took place at the headquarters of Hitachi Construction Machinery in Japan (Soka City in Saitama Prefecture), the staff from HCM and 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, a structure that blocks radiation to protect workers, as well as securing a workspace. Also, an expansion and contraction-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 at 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 with 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.