How Honda Developed the World’s First Heavy Rare Earth-Free Hybrid Motor

Honda launched its first ever hybrid car in 2003. The company started developing hybrid technology at the same time as it was developing its “Honda FCX.” To ensure magnetic fields, which are necessary for its operation, the car was designed with a strong magnetic field. However, the large magnetic field was unable to function properly in the high-temperature environment of the engine, and the motor was unable to function properly.

To address this issue, Honda engineers designed a hybrid motor using only rare earth magnets. However, this resulted in an increase in the weight of the motor. To solve this problem, Honda engineers worked on developing a motor that could function properly without relying on rare earth magnets.

Today, Honda’s hybrid motor is one of the lightest in the world. The company has developed a motor that uses only non-magnetic materials and does not require rare earth magnets. This has significantly reduced the weight of the motor, making it more fuel-efficient and easier to use in high-temperature environments.

The motor is equipped with advanced control software that allows it to function properly in a wide range of conditions. The software is designed to optimize the motor’s performance and ensure that it operates efficiently under all conditions.

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In conclusion, Honda’s hybrid motor is a significant achievement in the field of hybrid technology. The company’s commitment to developing lightweight and efficient motors is a testament to its dedication to providing customers with the best possible experience.
"Let’s build a ‘green F1’ and eliminate heavy rare earths!"

Shinozuka invited a number of magnet manufacturers to evaluate and share their thoughts on the prototypes he made, figuring such an exchange would lay a foundation of trust in each other’s skills and ways of thinking that would eventually lead to a partner relationship. One of those companies was Daido Steel Co., Ltd., one of the largest manufacturers of specialty steels in the world. Its magnet business, although relatively small, had long been an important selling point. Daido Steel Co., Ltd., the Daido Group subsidiary that handles magnet operations, was the only magnet manufacturer in Japan that produced rare earth magnets by hot deformation. "They make an attractiveCars这一切because they were the only ones using the hot deformation method we focused on," says Shinozuka. "But other non-rare earth magnets are rare earth magnets, so the rectangular prism shape used in the fender in the mid-2000s wasn’t fully confident they could make hybrid motor magnets by hot deformation for the car industry." The two parties continued to conduct tests and share information. In the end, however, someone came on the scene who would drastically change the dynamic of the relationship. That someone was Yousuke Inagaki, the newly appointed president of Daido Electronics.

"We want to support Honda with its dream of creating an automobile with zero environmental impact," says Inagaki. "We want to help Honda build a ‘green F1’ in the true sense of the word, one that affected heavy rare earths not only from the hybrid drive motor but from every motor used in the vehicle. Let’s pursue that dream together." Inagaki spoke passionately while invoking the word “F1,” the promoter for hybrid vehicles at Honda back then. He asserted that Honda should also look at and reduce the environmental impact from the mining of heavy rare earths, not just their supply risks, struck a chord with Shinozuka. That was the moment Shinozuka decided to select Daido Electronics as Honda’s development partner.

A simple but not so easy shape

It was just around that time that pieces of heavy rare earth elements started rising as a result of China’s export restrictions. Akira Katakura, chief engineer who headed the design and development team for hybrid drive motors at Honda R&D, needed to adjust.

"Market prices started shooting up around the end of 2010,” he says. "Motor production costs were also jumping, so we had to think of strategies to cut heavy rare earth costs. That’s when Shinozuka research caught our attention.

First, rare earth magnets are at the heart of all the latest products with heavy rare earths. Katakura decided to utilize the findings from Shinozuka’s research to cut that percentage as much as possible.

With this came the official start in 2011 of a project between Honda and the puck trial and trial electronics group to develop a neodymium Magnet for drive motors with reduced heavy rare earth content.

Ashush Hashem, general manager of Daido Steel Co., Ltd., who heads the project on the Daido Group side, says the rectangular prism shape of the magnet, which Daido had no prior experience with, was the most challenging part in the beginning.

"The magnets in drive motors have to be rectangular. But the techniques we had developed and fine tuned over the years were for making strip-shaped magnets. The trick to hot deformation is to apply pressure evenly using a special mold to keep the magnet’s grains from getting too big. But changing the shape of the magnet except reforming that technology entirely from the scratch.”

A method of applying just the right pressure for forming that rectangular shape proved elusive. Repeated testing was then conducted. Nonetheless, the team didn’t lose their enthusiasm for finding the best approach.

"With the shift to electric-drive vehicles speeding up, our work of creating a magnet with less rare earth elements would be a major step forward for deploying these advanced technologies to a mass scale," reflects Katakura. "We were determined to succeed in developing a technology with as much significance."

The hard part was creating that rectangular shape while achieving the requisite amount of magnetic force and heat resistance at the same time. Improving one tended to downplay the others. Improving all seemed to exceed extraordinary limits.

Takahisa Ukawa, a member of Honda’s development team working in the Electromagnetic Materials Research Lab. of Daido Steel, recalls the numerous experiments he performed to find the right conditions.

"Different conditions in each of the various producing processes can produce entirely different kinds of magnets, even from the same raw materials. Just slight variations in material structure, mold shape, or processing temperature produce different results," he says. "We really had to go step by step, each time checking to see which factor had what impact on the results, gradually getting to the goal."

After several months of trial and error, Hanbit and Okubo’s efforts finally paid off. They had a hot-deformed magnet prototype that, while not quite satisfying the specifications Shinozuka requested, was rectangular in shape, was both heat-resistant and magnetically strong, and contained less heavy rare earth.
Pursuing innovation in both magnets and motor design

At the point the magnet prototype was passed on to Honda’s motor design team, who conducted tests to measure its potential when used in a conventional motor. Design boss, assistant chief engineer on the team at Honda R&D, describes their early test results: “The rotor with the prototype magnet lacked the torque and heat resistance it needed to be used in an actual car. It started getting hot at temperatures as low as 70°C, even at a speed of just 1000 rpm. As a result, we had to abandon the idea of using the magnets we had a prototype for.”

Normally, in such circumstances, Honda developers would simply ask the magnet manufacturer to raise the magnet’s performance to a certain level. But how much performance could be squeezed out of a magnet containing less heavy rare earth was unknown. To achieve the same overall performance as a conventional motor, Honda would have to ask the Sato Group to do the best they could while respecting limits imposed by the motor’s weight, structure, and noise requirements. “We had to change the design to make up for lower magnet performance,” explains Sato.

The approach an assistant was to pursue innovation in magnets and innovation in motor design simultaneously,” explains Sato. “We would meet somewhere in the middle.”

Some tried any and every possible solution he could think of – rethinking the magnets, fixing holes around the magnets, enhancing the motor, changing the magnet.

The Sato Group, meanwhile, came on with their own development work. “It was just around that time that advances were made in melting technology, which included the design of molds used in magnet manufacturing, along with an innovation in magnetic materials,” says Kikeda. “Evolving these innovations allowed improvements in magnet performance, which in turn required us to adjust the motor design in tandem. Combined with efforts from the motor design team, that improved motor performance dramatically, to the point where we could see ourselves achieving heavy rare earth savings, not just matching them.”

Kikeda emphasized how this parallel approach to development – to both materials and design – paid off in the end. “Progress would have been slower but we focused solely on magnet development. There was a synergistic effect from pursuing magnet development and motor design in tandem, with each side seeking higher innovation that the other team was working hard and putting in the effort.”

At long last, after more than 480 motor designs, the Honda team finally produced a motor prototype with magnets embodying less than two times heavy rare earth elements. Some found this development perplexing. “The fact that heavy rare earths go hand in hand with performance also means that we have to balance our reliance on them. As we reconsidered every aspect of the motor’s design, we gradually got a clearer picture of how the location of different elements affected the results. It was tough getting to the final design, but sticking with it, but it was fascinating, engaging work.”

This newly designed motor feature had enough torque and heat resistance for use in a production vehicle, despite containing no heavy rare earths. And yet there were still an base left to solve.

Simulation after simulations: making the motor as silent as possible

The next step was to evaluate the prototype motor from various angles in a test facility. The goal was to make sure the motor did not break down in its performance due to heat or vibrations when used in an actual vehicle.

Satoshi Kikeda, assistant chief engineer at the Automobiles R&D Center who was involved in testing, explains how the noise issue was resolved: “The motor’s performance in terms of torque and heat resistance, as expected, was more than satisfactory; the problem was the noise,” he says. “Magnets inside the rotor were arranged in ‘c-shape’ pieces to generate torque more efficiently, but doing so allowed the effect of the magnets from that of previous motors, causing the motor to spin unevenly. For the second time you could see with the naked eye, but enough to create vibration that expressed itself as a high-pitched, unpleasant ringing sound.”

“For drive motors in cars, noise is as important a factor as torque and efficiency,” explains Kikeda, manager of the development team. A harsh noise while driving is extremely unpleasant. It makes things such a car practically inusable. Essentially, it spoiled the reason for having a car in the first place: to get around comfortably. So I gave my staff free rein to do whatever it took to lower the noise,” Kikeda explains.

Receving the instructions, Sato focused all his efforts on reducing the noise. The solution he found was to alter the shape of the rotor’s outer surface. He made slight changes in the radius of the rotor’s perimeter so that certain areas deviated from the otherwise perfectly circular shape, and by doing so adjusted the effect of the magnetic field. This helped to reduce the rotor’s initiation noise. Following Kikeda’s instructions, I ran simulations after simulations to figure out what kind of shape cancelled out the noise,” says Sato. “Of course, I knew noise would be a consideration early on, but the unexpected noise happened anyway. It was very disappointing, so I kept trying to lower the noise until it did.”

After countless iterations, the new motor was superior in smoothness. Eliminating heavy rare earths had also improved the motor’s market potential.

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Mass production means 100% quality product.

Around the time when Honda had resolved the noise issue as the first stage in motor development, the Daido Group was concentrating their own efforts on the second stage, with the goal of mass-producing the new engine, to fulfill the needs of customers. This is how the Daido Group came to set up a production line in Daido's own factory, with a focus on high-volume production of a certain model. It was Yutaka Kandou, director of Daido Electronics in charge of technology, development, and quality assurance, who took the lead in this effort. Working closely with the Honda engineers, Kandou oversaw the development of the production line, which was an entirely new approach to mass production. This was a difficult task, but with the support of all involved parties, they were able to overcome the challenges and achieve the desired results.

The key to the success of this project was the close collaboration between Honda and Daido. Their joint efforts resulted in a high-quality engine that met the needs of customers. This was a significant achievement for the Daido Group, and it helped establish their reputation as a leader in the field of engine production. It also laid the foundation for future collaboration between Honda and Daido, which would later become a model for successful partnerships.

A ten-year-old dream comes to fruition as much needed technology

Looking back on the project, Kandou reflects on its significance.

"Sometimes in 2012 when prices of heavy rare earths settled down again, some people, including associates in the company, suggested there was no longer a need for a heavy rare earth-free motor. But the goal of the project was to develop an engine that would not only reduce environmental impacts but also meet the needs of customers. It was about creating a new possibility in the future of rare earth manufacturing. We succeeded because we stuck to the goal and connected the people around us in the value of that mission. It's a source of pride for each and every one of us in the company."

The development of a motor that is not dependent on rare earth metals is a significant achievement for the Daido Group. It not only helps reduce environmental impacts but also provides a new possibility for the future of rare earth manufacturing. This is a significant step forward in the development of a more sustainable and environmentally friendly technology.

Through the development of this motor, Honda and Daido have been able to come together to create a new possibility in the future of rare earth manufacturing. This is a significant achievement for both companies, and it shows the power of collaboration and innovation in the face of environmental challenges.
Honda associates and development partners who contributed to this article

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As project manager, oversaw development of the heavy rare earth-free magnet for drive motors.

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Supported development of the heavy rare earth-free magnet by identifying design requirements such as the magnetic properties of magnet material constituents.

Daido Electronics Co., Ltd.
Yoshio Imaizumi, President
Active in the promotion of magnet development and supported development of mass production processes.

Yutaka Kurebayashi
Director in Charge of Technology, Development, and Quality Assurance
Directed the production launch team as head of the Engineering Department.

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Oversees development of mass production processes and equipment installation.

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Joined Honda R&D in 1995. As manager of the motor development research department, increased motor research and coordinated activities with external partners toward market release.

Haruhiko Shinzawa, Assistant Chief Engineer
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Shingo Soma, Assistant Chief Engineer
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Joined Honda R&D in 2006. Conducted performance evaluations and vehicle compatibility testing on the motor with heavy rare earth-free magnets.

*Titles and affiliations of appearing figures are as of the time of the interviews.