Powering the Bullet Train

The world stands on the verge of a new era in rail travel. Numerous high-speed intercity rail projects have been announced, as countries realize the advantages of rail as a safe, reliable means of mass transit that does not burden the environment. Much attention has come to focus on Japan's Shinkansen (bullet train), which has been transporting passengers at speeds of over 200 kilometers per hour since it began operating in 1964 and has a remarkable safety record of zero passenger fatalities.

The technology that drives this world-renowned rail network is not concentrated just in the hands of major train makers like Hitachi and Kawasaki. Alongside the control systems and rail infrastructure, the outstanding technologies developed by numerous small and medium-sized manufacturers help to ensure that the Shinkansen remains one of the fastest, safest railways in the world.

Sanwadenki

Automating the Production of Motor Coils

Japan's world-class Shinkansen bullet trains are geared first and foremost at smooth and extremely safe travel at high speeds. The company that manufactures the motors for the trains is Sanwadenki Co., Ltd., located 100 kilometers north of Tokyo in Tochigi Prefecture. With just 70 employees, Sanwadenki supplies motors for both domestic and foreign train manufacturers.

In addition to the Shinkansen, its motors can also be found on trains in Asia, Europe, North America, and Africa, including China's high-speed rail system and the New York and Washington DC subway systems.

Sanwadenki has drawn international attention for developing equipment to fully automate the production of the coils used in train motors. Prior to this achievement, coil production was a time-consuming process requiring highly skilled craftsmanship.

Four Innovative Machines

The first step in Sanwadenki's new manufacturing process is to make a base for the coil by using a winding machine to bundle copper wire into an oval shape. Automation allows the base to be created in a uniform shape, regardless of the wire's hardness or thickness. This obviates the manual task of hammering the wire and the associated risk that the wire may be inadvertently damaged.

The next step is wrapping the oval-shaped copper coil in insulating tape. The tape must be wrapped with a specific, uniform tension to ensure that it is neither too tight nor too loose. If the tape is wrapped even a little too thick, it will not fit inside the drum container; if it is too thin, it will not be able to withstand the several thousand volts of electricity that must pass through the coil to power the train. This is an intricate process with a margin for error of less than 10%.

Toshio Fukuda, president of Sanwadenki Co., Ltd.

For this stage, Sanwadenki uses a track coil taping machine capable of rotating 250 to 400 times per minute to apply a uniform wrapping of tape. Though wrapping straight wire is not very difficult, covering curved and twisted sections of coil can be tricky. To solve this problem, the company uses a computer to control the speed and angle of the wrapping, allowing even the more difficult surfaces to be taped without error.

The next step is to prepare the coil for the final and difficult shaping process, and this involves using

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Capital: ¥30 million
Employees: 70
Website: www.sanwadenki.co.jp

a pre-forming machine to shape the coil into an oblong.

Lastly, the coil is given its final shape using a forming machine. Hammering has been eliminated from this stage as well, so there is no danger of damaging the coil's surface.

With the development of these four machines, Sanwadenki has revolutionized the motor coil manufacturing process. A task that once took 40 minutes of manual labor can now be performed in as little as 6 minutes, depending on the particular coil specifications. And while in the past maintaining uniform quality throughout a coil was a challenge even for highly skilled craftsmen, now any employee trained to use the machines can produce high-precision coils with ease.

The Long Road to Development

Sanwadenki got its start manufacturing printed circuit boards for transistor radios before it switched to producing motors for trains. The company was struggling to turn a profit because of the sheer level of technology required when a flood struck that inundated its factory and destroyed nearly all of its parts and machinery. The following year saw the privatization of one of its main customers, Japanese National Railways (now Japan Railways), and several years later came the collapse of Japan's bubble economy. This series of challenges and hardships left the firm's business in dire straits.

"We were faced with two choices: either quit motor manufacturing or revamp our entire operation," recalls Toshio Fukuda, president of Sanwadenki. "At that point I wondered if there was a way to automate production so that it could be done even by those without highly specialized skills. Not everyone at the company, though, agreed with the decision to develop such machinery."

Initially the company outsourced the production of the machinery, but development did not go as planned. Three years of effort resulted only in a string of failures. Uniformly coiling the copper also proved daunting owing to the varying hardness of the wire, and while the firm succeeded in automating the wrapping of straight sections of coil with insulating tape, corners were a different matter.

It was extremely difficult to wrap the wire precisely—the tape could not be wrapped around the coil with uniform tension, resulting in sagging or shriveling. After numerous failed attempts to overcome these challenges, Sanwadenki decided to try and develop the machinery itself, putting its employees with engineering backgrounds to the task of finding a solution. Four months later, the company's new machinery was complete.

Inserting the coil into the drum, the final stage of motor coil production.

Responding to International Needs

Soon after its completion in July 1994, the new system was exhibited at a trade show in Milan, where it caught the eye of a South Korean manufacturer. Thereafter, orders began pouring in from US and Canadian companies. "We now receive inquiries from all over the world," says Fukuda. "When we first completed the system, we never imagined it would one day be used in the motors of trains around the world. What enabled us to create this system was the fact that we specialized in making coils, not machinery. Knowing the challenges and intricacies of coil production allowed us to create machinery that both elevates the degree of precision in our products and is also easy to operate."

But Sanwadenki's dedication to quality extends beyond the development of this revolutionary system; it also places great importance on maintenance and other aspects of after-sales service. Its entire factory is open to public viewing, from the operation of its machinery to its systems and administrative techniques.

"We want people to come and tour the factory and see the products for themselves," says Fukuda. Visitors from overseas are common, and members of the international sales staff are on hand to provide answers to questions requiring detailed knowledge. "We have a quick response time, including for overseas clients. For locations in Asia we're on-site the following day." Such commitment to timely customer service is another factor helping Sanwadenki earn the trust of clients all over the world.

Yamashita Kogyosho

Hammering the Shinkansen into Shape

Bang, *bang*, *bang*. A rhythmical, metallic clanging issues from the grounds of the Yamashita Kogyosho factory. It is the sound of the company's highly skilled workers hammering away at sheets of aluminum, their gaze fixed intently upon their work. Hammering out sheet metal is a unique skill and one in which the company, whose head-office-cum-factory is located in the corner of an industrial park near the Seto Inland Sea in southern Japan, possesses unrivaled proficiency.

The end result of this highly skilled hammering is pieces of metal that will serve as the noses, or elongated front sections, of Japan's world-renowned Shinkansen bullet trains. At this small factory, 35 employees work to produce noses for the N700-series Shinkansen, the latest model used on the Tokaido and San'yo Shinkansen lines connecting Tokyo, Osaka, and Hakata, and the E-2 and E-5 trains used on the Tohoku Shinkansen line connecting Tokyo and Hachinohe in northeastern Japan and other lines. The company was also responsible for making the noses of the original 0-series Shinkansen launched in 1964.

Like the automobile, the Shinkansen represents a "crystallization of cutting-edge technologies," but what many people do not realize is that it is human hands, not precision machinery, that are responsible for fabricating many of its parts.

Experience and Intuition

Hammering sheet metal involves using a hammer to expand and shrink sheets approximately 1 to 6 millimeters thick to form subtly curving surfaces and other shapes. While a blow from a hammer depresses the area struck, it causes the surrounding area to bend back toward the blow, resulting in a slightly raised surface. The process is repeated to give the metal a curved shape. A finished metal sheet acts as a template against which workers can verify the accuracy of their handiwork, but when actually hammering and checking the effect of their blows they rely solely on their eyes and hands, repeatedly hammering and checking to ensure precision. Experience and intuition are an integral part of this highly skilled craftsmanship.

Hammering an aluminum sheet into shape.

President Tatsuto Yamashita, left, speaking with factory supervisor Jiro Kunimura.

Jiro Kunimura is the supervisor of Yamashita Kogyosho's factory and a recipient of the Ministry of Health, Labor, and Welfare's 2008 Outstanding Skilled Workers award. "I've been hammering metal sheets for 45 years, yet I've never once been completely satisfied with my work. This isn't the sort of job where you can just push a button and make the metal curve in a particular manner," he says, hinting at the high level of the artisanship involved.

President Tatsuto Yamashita likens hammering sheet metal to traditional performing arts. "You can't learn the subtleties of this technique through instruction; nor is it something that you can write down in a manual. It's like golf: no

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Capital: ¥10 million
Employees: 32
Website: www.yamashita-kogyosho.com (Japanese only)

one can teach you how to hit a drive exactly 300 yards," he says with a smile.

Kunimura agrees. "It takes ten years to become truly proficient. The fastest way to make progress is using your hammer to check whether the metal feels right. The most important attribute in this line of work is perseverance."

Low Costs and Flexibility

The biggest advantage of shaping sheet metal by manual hammering is the lower cost, as there is no need for specialized molds. The rival technique of cutting the metal into shape involves either cutting with expensive machinery or using a special metal press and then applying heat to prevent the metal from springing back. But these techniques incur a variety of costs, such as those of transporting raw aluminum and disposing of excess metal. Compared with the alternatives, says Yamashita, manual processing "enables us to trim costs to one tenth and processing time to one hundredth."

Moreover, shaping the metal at normal temperatures avoids the warping that occurs with the application of heat, making it possible to turn out sheets with a high degree of precision.

Flexibility is another advantage of manual production. According to Yamashita, engineers working on the manufacture of train cars at Hitachi's Kasado Plant in the city of Kudamatsu, Yamaguchi Prefecture—for which Yamashita Kogyosho is a partner company—often visit in the morning and demand changes they want in place by evening. This ability to accommodate sudden changes in design is one of the company's hallmarks.

"With machines, changing the design would necessitate a lot of work, including the overwriting of CNC lathe data," Yamashita emphasizes. "But it's something that we can manage from a single blueprint when the work is performed by humans."

The Aluminum Cello

The company is involved with more than hammering sheet metal, however. One of the factors that has enabled it to leverage the advantages of hammering so far is the fact that Shinkansen parts have tended to be ordered in small lots. With JR now operating shorter Shinkansen trains more frequently, though, Yamashita Kogyosho is grappling with the challenge of increased demand for train noses.

In order to meet this demand, the company is working on automating the processing that takes place before the sheet metal is hammered. For example, lasers will be used to trim the parts from standardized pieces of aluminum, and work that requires bending sheets at right angles will be done using a press. "We have to automate things that can be performed by machines if we want to move forward," says Yamashita. "However, there will always be some work that can only be done by hand."

Another challenge is how the company will hand down its expertise to the next generation. The average age of its employees is over 50. "We notified an employment agency of a job opening at the factory, but none of the agency's staff—let alone the jobseekers—had even heard of the technique of hammering sheet metal." Yamashita was unable to hide his shock at this revelation.

To raise the profile of this technique, he decided that the firm should create a cello made entirely of hammered aluminum. Through trial and error, workers at Yamashita Kogyosho managed to hammer a 4-millimeter-thick piece of aluminum down to 1.6 millimeters and into the shape of a cello. What is more, the sound produced by the instrument is on a par with that of a wooden cello. "I wanted to prove that a hammer could be used to fashion the delicate curves of a cello," Yamashita says passionately.

Aluminum cellos built by Yamashita Kogyosho's artisans.

He plans to put the cello on display at events and various exhibitions, not only to showcase the company's expert craftsmanship but also to raise awareness of hammered sheet metal. Yamashita proclaims, "My dream is that the instrument will one day be played by world-renowned cellist Yo-Yo Ma." HJ