Leading-Edge Technologies and the Future

By Karatsu Hajime

Japan has quite a few industries that boast the top production quantities in the world. Though it may come as a surprise to many, Japan continues to produce 10 million passenger vehicles per year, the highest output in the world. Also, not only does Japan rank highest in the world in motorcycle production, but 33% of the machine tools the world uses to make motorcycles are made in Japan. Of industrial robots, 70% are made in Japan. The list goes on and on. In consumer products, Japan produces more than seven million digital cameras, the hottest new consumer item, per year, and has a virtual monopoly in the areas of car navigation systems and video games. And 70% of the silicon used in semiconductors, which are used to create these products, is also supplied from Japan. The long-life lithium-ion batteries used in mobile phones were discovered in Japan, and 100% of those batteries are now made in Japan. Clearly Japan is at the top of the market in the manufacturing of numerous products, and the technological capabilities that have resulted in the production of these goods are an important resource for the Japanese economy today. In gross domestic product (GDP) terms, Japan has an enormous economy valued at ¥500 trillion, or about 15% of the total world economy.

Many industrial products are made of steel, and the iron ore used to make that steel costs about ¥2,000/ton when it is imported into Japan. Once it is processed and formed into sheet steel, it costs ¥50,000/ton. If it is used to make a car, the price rises to ¥1 million/ton. The added-value generated by processing raw materials into finished products is the driving force behind the Japanese economy. And of course technologies are needed to create finished goods. Hence, our first conclusion: Japan's enormous economy is based on the creation of industrial products, and the motive force behind the creation of those products is the nation's technological capabilities.

However, technologies change quickly. If a company is not constantly engaged in developing new technologies, its competitiveness will quickly dwindle. For this reason, Japanese firms are investing enormous amounts of money into research and development each year. Those investments are valued at about ¥16 trillion per year, or about 3.2% of the nation's GDP. This is quite high when compared with the average of 2% among other industrialized countries. We can only hope that the Japanese government fully recognizes that Japan's competitiveness is currently being sustained by those investments, and will offer incentives to firms that pursue them.

A recent story from the shipbuilding industry demonstrates the amazing things technology can do. It once seemed that the shipbuilding industry had been lured away from Japan by South Korean firms, but now the Japanese firms seem to have taken it back. With a 40% share of the market, Japan's shipbuilding industry is now the world's largest. The reason for this shift is the change in the types of ships being ordered and the unique technological innovations that have been developed in Japan's shipbuilding industry. Ships are not made simply by bending steel sheets. The curved surfaces of the various kinds of steel sheets supplied by the ironworks must be made to fit the ship's blueprints. Until now, this work was all done manually by professional craftspeople, requiring both a lot of labor and a lot of money.

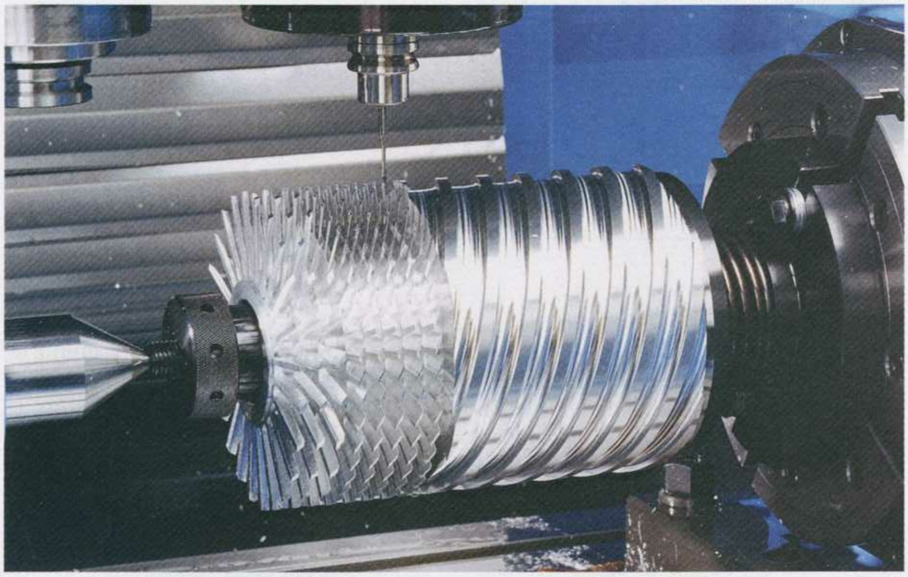
Just recently, however, I had a chance to see some amazing processing technologies at work at a shipbuilding plant in Kobe, Hyogo Prefecture. The plant had plans to build five 50,000-ton container ships. The first one took 64 days to build, and the second was completed after only 58 days. At a whopping 50,000 tons each, these ships stretched nearly 200 meters. It once would have been completely unthinkable that they could be built in such a short period of time. The speed of delivery, that is, the ability to deliver a ship to the ship owner by the requested deadline, and according to the specifications, is one of this company's main sources of competitiveness.

It is the incorporation of information technology (IT) into shipbuilding that has made this kind of progress possible. Advanced IT systems are being incorporated into all kinds of factories, and in this industry, computer-operated robots can be used to create these enormous products. Exactly how this firm produces what they make is a company secret, of course, and although there is no way for someone from the outside to know exactly how they do it, their secret has to be related to the company's incredible technological capabilities. When I asked this Kobe boat building manufacturer to confirm this, I learned that orders are being placed for vessels weighing nearly 65,000 tons, that are nearly as large as the width of the Panama Canal. All of this indicates that Japan's shipbuilding industry has once again taken the top spot in the world.

It is important to emphasize that the driving force behind what happened here is technology. This example shows how the Japanese shipbuilding industry, which had been usurped by companies that could operate at lower cost in South Korea, regained its top position thanks to new technologies and the delivery speed they made possible.

In today's world, where things change so rapidly, delivery speed is often a decisive factor in a company's competitiveness. In the Shinjuku district of Tokyo, there is a company that produces virtually 100% of the molds used in the highly competitive mobile phone market. Customers can get delivery of their finished products just three days after placing an order with the company. Here's

Photo: Matsuura Machinery Corporation



A machining center made the fuel tanks on space shuttles four tons lighter by shaving the aluminum-lithium bars at ultra-high speeds

how they do it. The molds are created using CAD, or computer-aided design. But a designer cannot know just by looking at the CAD image whether a design will work. So the output is fed into a laser shaping machine. This way the design can be adjusted with micron-level precision. Laser shaping machines cost about ¥80 million, but in the end they are well worth the investment.

What such stories clearly demonstrate is that developing a new technology is not just about developing a single technology, but about combining many diverse technologies to achieve something new. In this regard, technological development differs from the world of science, which recognizes the value of each new discovery in and of itself. As the purpose of a technology is to create new goods or achieve new functions, it cannot succeed if periphery technologies are not also fully developed.

If we look at it this way, then Japan actually has a number of advantages for developing new technologies. Until recently, it was commonly believed that companies would be best off looking toward the United States for new technologies, and in many cases that was true. But now the world has changed. Today there are quite a few technologies that can only be found in Japan. This is especially true in the area of processing technologies and molds used in the manufacturing sector, where Japan is ranked top in the world.

Four tons of weight were recently shaved off the fuel tanks on the U.S. space shuttles. This was achieved using an ultra-high-speed machining center operating at an amazing 65,000 revolutions per minute, a tool developed specifically for that purpose by a machine tools manufacturer in Fukui Prefecture. This machine shaved off four tons the first time it was used. Four tons, incidentally, equals the weight of an entire truck. The somewhat amusing down side of this achievement was that the customer, who had initially ordered 26 of the machines, was able to do what was needed with only four because of the unexpected results of the excellent machines, and ended up canceling the rest of their order. This left the manufacturer with the challenge of having to sell the rest of the machines.

All of the big three U.S. automakers, including General Motors (GM) of course, purchase molds for vehicle bodies from Japan. Molds produced in the United States will soon be out of use after 30,000 body-making processes, while Japanese-made ones can be used 60,000 to 100,000 times. Recently, Mercedes also began using Japanese molds. You can be quite certain that the Mercedes-Benz cars you see in Japan were produced by using Japanese-made molds.

As these examples show, many of Japan's periphery technologies are also the best in the world. But there is a major concern at the workplaces that use these production technologies: the aging of their workers. Statistics show that the average age of workers at factories that produce molds is 53 years old. This begs the question: what's going to happen in the industry over the next 10 years?

It is difficult for firms to take the necessary steps to battle this trend on their own. One necessary step is to convert tacit knowledge into explicit knowledge. The Ministry of Economy, Trade and Industry is struggling to make this happen. The mobile phone mold sector mentioned earlier is one sector where this has worked. If tacit knowledge can be successfully converted into explicit knowledge, conventional skills can be replaced with IT.

As mentioned above, the company that makes mobile phone molds delivers its completed products in three days. According to the company president, the young people who use CAD at this company are non-professionals, such as part-time workers. After two months of training, they are then able to use this design tool with a modicum of skill. If a company skillfully develops IT software and has the secondary equipment needed to support that software, the unskilled young workers can do the same level of work as master craftspeople. In this case, the key to the company's success is the laser shaping machine. Using this machine, a worker can achieve a sample that is highly precise at the micron level. This is a step beyond what can be achieved by looking at a conventional cathode-ray tube display, and enables the worker to confirm the precision of the design. It is wonderful advantage for the designers to be able to know in the design stage all of the conditions that will exist when a product goes into mass production. This allows them to complete their design without having to conduct repeated trials and errors. This example shows the possibility of the conversion of tacit knowledge into explicit knowledge.

This has completely changed the world of auto development too. In the past, manufacturers had to create at least two test vehicles when developing a passenger automobile. This requires large costs and a lot of time. With recent IT developments and the practical use of various shaping machines using CAD, the development lab has changed dramatically.

The same is true for test models of airplanes. Not only have development times shortened, but it is also now possible to conduct breakdown tests that the developers wanted, but were unable to perform in the past. This is another example of a shift from tacit knowledge to explicit knowledge.

What direction will Japan's new technological developments take in the future in response to the advancements taking place in factory technologies? The following are five major areas of application for Japan's new technologies in the future.

(1) Information Technology

First is the field of information technology, or IT. There are important preconditions that may effect how useful IT can be, however. Information in and of itself has no value. Its value comes from how it is used and interpreted. Mere numbers and symbols on pieces of paper may as well go in the scrap heap. The key to a company's success lies in its ability to read this data, and therefore in the company's acquisition of analytical techniques for doing so. For this, a company needs someone with experience in a series of techniques, starting with statistics. Without a basic knowledge of such concepts as operational research, linear programming, matrix theory, multivariate analysis and game theory, IT is of little more use than an abacus.

It seems that every small retail shop these days has a cash register, and some of those even have computers. With a computer, it is easy to track the products sold, as well as a range of details about each sale from the time of the sale to the type of customer, depending on the store's needs. Chain stores that use computers are linked electronically, and their head offices can see all the records for all the sales their stores make. Some of these use this technology strategically to deliver or collect products as needed. The key here is how IT is being used. Statistical reading is also needed for determining how to use and distribute information. Just sending out numbers will not be useful. Every day, trains make 230 round-trip journeys along the Tokaido Shinkansen (Bullet Train) line, picking up and dropping off passengers right on time. This is made possible, of course, by IT, though people do not generally realize it. In fact, the ability to exert influence over areas of everyday life without people ever being aware of it is a special feature of IT.

(2) New Materials and Processing Technologies

A current development in the steel industry is the mass production of ultra-high-strength steel. Steel materials that are 1.5 to 2 times stronger than conventional steel began to be mass produced last year. Stronger steel makes it possible to built lighter cars, and changes building design. This innovative steel material was developed in Japan based on a principle discovered at Tohoku University 10 years ago. If the iron crystals in the steel are reduced to one-tenth of their normal size, the strength of the steel can be more than doubled. It was quite difficult to develop this principle into mass production, but this was finally achieved in 2002. This development will completely change how steel materials are used.

There have also been innovations in processing technologies. As mentioned earlier, the weight of the fuel tanks on space shuttles has been reduced by four tons. This was achieved by replacing duralumin with lightweight aluminum lithium. Unlike duralumin, however, this material cannot be made in sheets. It has to be shaved off. However, because of its sensitivity to temperature, it will ignite if it is not shaved off properly. So it must be shaved off with incredible speed. Instead of being shaved off at a maximum speed of 25,000 revolutions per minute, it is now done at 65,000 revolutions per minute. Thanks to these new machine tools, the tank can now be made four tons lighter than before.

These examples demonstrate how Japanese materials and processing technologies are opening up a whole new world. It is no longer rare for polishing to achieve a micron-level precision of the final product, and with recent advancements in nanotechnology, processing is now being done down to a one-one billionth level of accuracy.

(3) Life Sciences

Today, we are experiencing a boom in the life sciences, and it seems that every day some new possibility is discovered. When attempts are made to develop applications for those discoveries, however, scientists often find that there is still a great deal that we do not know, or run up against questions about the phenomenon of life itself, raising ethical questions and other problems. For example, scientists have learned that, by examining a person's genetic makeup, they can predict whether the person will be at risk of high blood pressure when he or she reaches a certain age. This raises the question of whether such information can be used in hiring decisions, and that in turn has implications for human rights.

With such rapid developments taking place, various studies need to be conducted on how these developments should be handled. Especially as studies in the field of medicine focus on life itself, it is important to note that the development of conventional technologies that dealt with physical objects was done in a completely different way. There is still a great deal that we do not know in this arena, and the addition of nanotechnologies is sure to produce yet a whole new world.

(4) Energy

The present issues are fuel cells and nuclear fusion, practical applications for which are not too far out of reach. Several passenger car makers in Japan have announced that they are going to market cars that run on fuel cells. This fact reminds us that, about a decade ago, while the United States was still issuing gas emissions regulations, Japanese manufacturers succeeded in producing low-emission vehicles.

The government is also very interested in promoting the widespread use of fuel cells, and has issued tax incentives for this purpose. In that regard, however, hybrid cars should not be ignored. These cars combine a standard gasoline engine with an electric motor, resulting in low fuel consumption and low emissions. And with their low cost, hybrids probably represent an even better option than cars that run completely on fuel cells, given the technologies available today. Toyota Motor Corp. was the first to market this kind of car, but after they become popular among drivers, other auto manufacturers began to follow suit.

Since the raw material used for nuclear fusion is heavy hydrogen, which can be produced using seawater, the development of successful applications for nuclear fusion would single-handedly solve all of Japan's energy problems. This is a truly time-consuming development, however, and the United States actually withdrew from the international joint development team that was conducting research in this area. With new prospects for this technology now opening up, however, the United States is asking to be allowed back onto the team. While this may appear self-serving, this fact alone suggests that researchers are getting close to achieving practical applications for this technology. Nuclear fusion research centered around superconductive magnets and high-powered lasers represents the cutting edge of research today. Now that goals have been identified for this technology, the pace of research is sure to accelerate.

(5) Space Exploration

Japanese space exploration has had a long history since Uchinoura in Kagoshima Prefecture. Japan was the third country in the world, behind the now defunct Soviet Union and the United States, to successfully launch a satellite into space. Also, unlike military space programs overseas, the Japanese program initially started off under the budget of the then Ministry of Education (now the Ministry of Education, Culture, Sports, Science and Technology), and was therefore only about one-tenth the size of other countries' programs. I was involved in the launching of that satellite, and can tell you that the process was extremely difficult. One Diet member refused to accept the use of a guidance system. He insisted that the guidance system could be used as a weapon – a possibility he deemed unacceptable. It is no easy feat to launch a satellite and get it to orbit the earth without guidance. In fact, it took several tries before we were successful. When it finally happened, the joy of the accomplishment made those who were involved feel like we could almost touch the sky.

It is very likely that there is no satellite anywhere in the world that was built at a lower price than Japan's. Japan will strive to launch satellites by further improving this technology, and it will be truly exciting to see how things develop in the future.

This is just a rough list of the new technologies currently being developed. Japan is also on the leading edge of nanotechnology research, and is achieving amazing results. This remains an exciting field to watch.

I'll say it again. The private capital being invested in the development of these new technologies amounts to about ¥16 trillion, or 3.2% of Japan's GDP. Overseas, that figure is no more than 2%, making Japan's investment exceptionally high by comparison. For this reason alone, Japanese firms are inevitably going to take risks on new ventures, and this gives them a great deal of future potential. And this potential is not limited to fields of so-called advanced technology. Even in less conspicuous arenas, there are plenty of Japanese firms making some of the best products in the world.

The world's leading manufacturer of ship propellers, which is located in Okayama Prefecture, is famous for making propellers that do not produce foam. The production of foam means that a lot of energy is being wasted. For that reason, many ship owners use this company's propellers, even if they have the body of the boat built elsewhere. Firms that have monopolized the market this way are referred to as "only-one companies."

When the lithium-ion batteries used in mobile phones first began to come into widespread use, a company in Sumida Ward in Tokyo was the single, solitary supplier of their stainless steel cases. This was the only company that was able to condense the stainless steel case into the size of a pencil cap. It had only six employees.

A company's technological capabilities have nothing to do with its size. Even the above-mentioned machine tool maker that shaved off the fuel tanks for space shuttles successfully developed the ultra-high-speed machining center that other companies had been too intimidated to try to make themselves. They were presented with a number of challenges that had to be overcome. First, they needed an ultra-high-speed motor. When they approached a motor specialist, they were told that such a motor was impossible. After making an impassioned plea, the motor company agreed to give the tool maker the core and other parts, and suggested they try making it themselves. When the tool maker did just that, they burned up all the bearings. So they purchased bearings from all over the world and continued to conduct tests. Only one company's bearings were able to hold up at their high speeds. They were able to use these bearings to build the machine, but they could not determine a technological reason for why the bearings were able to hold up. After two years of research conducted for the company by a university, they learned that the crystals that made up the bearings had a radial shape. It took another two years to create the same material. This is the nature of technological development.

Japan has an advantageous environment for these kinds of technological developments. No matter what someone wants to try to develop, Japan has all the technologies available. As long as things remain this way, Japan will surely continue to produce some of the world's most advanced technologies, and will also continue to export those technologies to other parts of the world. This is clearly demonstrated by the fact that Japan's overseas production accounts for 24% of its total production. Indeed, it is important that the world recognize just what is happening in Japan today. JJTI

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