PHOTO COURTESY OF THE MACHINE TOOL MUSEUM

Tools that Create

A short drive through the verdant hills of the Basque country from the resort town of San Sebastian, the Machine Tool Museum occupies a rustic open space in the center of the small city of Elgoibar. The museum tells the story of the region's machine tool industry—beginning centuries ago, when ironworkers took advantage of high-quality local ore to create grillwork for cathedrals around Spain, and people began developing machines to shape those pieces. Spain's machine tool sector is now the third largest in the European Union.

From bicycles and guns in the early part of the last century to airplanes and automobiles today, the industry has continued to grow and innovate, propelled by research on how to meet ever-changing consumer needs. This research takes place both within companies and at a network of research centers funded by local companies in partnership with national and local governments.

Nicolás Correa, the top milling machine producer in Europe, sells machines that help shape parts for automobiles, airplanes, and windmill blades.

PHOTOS COURTESY OF NICOLÁS CORREA

Process of Creation

Behind nearly every product in use today are the machines that created it. "Machine tools are enablers of almost everything in the world," says Javier Eguren, managing director of the milling-machine manufacturer Nicolás Correa, who was recently appointed president of the European Committee for Cooperation of the Machine Tool Industries. "They transform prime materials, metals, and other components, to get the shapes needed." Processes such as cutting, stamping, milling, drilling, grinding, and boring all form part of the process that, for example, creates the tools and dies to turn sheets of metal into automobile parts.

Machine tools have gone through a number of technological revolutions. A hundred years ago, many machines in a room were often powered by a single motor that turned an axis that propelled a belt whirring along the ceiling. That belt transferred energy to axles, which in turn transferred it to the machines themselves. A major change was the introduction of machines with their own independent motors. In the 1970s came computer numerical control (CNC), in which machining operations are directed by software. Today the vast majority of machine tools produced in Spain are equipped with CNC.

"That was really the largest change in the industry," says Eguren. "Since then, I'd say the major changes have been through advances in productivity and precision." Machines today are exponentially faster and more precise than those available only 20 years ago.

A number of innovations have made those changes possible. As machines increase in both size and speed, retaining precision remains a challenge. The machines heat up as they work, and this increase in temperature causes metal to expand. "So measuring precisely is one of the big research areas in this industry, to know exactly where you are at all times with your tool," says Eguren. One research goal, he says, is to reduce errors down to the order of only a few microns.

Nicolás Correa has made milling machines for more than 50 years, selling them around the world; it is now the top milling-machine producer in Europe. These machines tend to be geared toward shaping large components, such as dies for shaping the body of a car or the structural components of an airplane. More recently the company has focused more closely on the growing energy sector, creating machines to shape components of windmill blades. It also creates specialized, flexible machines.

To add value to its machines, in 2007 Nicolás Correa spun off a company called GNC Laser, which patented a laser technology that could repair, for example, holes in components caused by a slip in the machining process. This same technology can also harden the surface of dies degraded by the stamping process.

The Danobat companies, which together form one of the largest machine tool corporations in Spain, are world leaders in machines to grind blades used in airplane engine rotors. The Danobat research center, Ideko, focuses exclusively on developing improvements for machine tools.

Fagor Arrasate, a mechanical-press manufacturer and one of the largest machine manufacturers in the region, has taken advantage of improvements in motors to redesign its presses. The company is now able to make larger presses that are flexible enough for customers to quickly change the profile of a piece. It's also developed a high-speed robot that hovers in the narrow spaces above presses and can quickly move pieces between machines.

"We're also developing new systems to reduce the consumption of energy, materials, and oil," says David Chico, product development manager of Koniker, the research center of Fagor Arrasate.

Fagor Automation manufactures solutions for machine-tool automation. Recently the company has improved the precision of the machining process through advances in what are known as encoder systems. In a new building raised only four years ago, the new system determines the

Fagor Automation (above) provides systems that computerize and enhance the precision of machines, while the milling and boring machines from Juaristi (below) allow customized solutions for customers.

PHOTOS COURTESY OF FAGOR AUTOMATION AND JUARISTI

location of products being processed by analyzing light passed and blocked by a series of lines on the scale of only hundredths of a millimeter. The technique involves etching glass and depositing layers of chrome and resins in carefully controlled environments where the temperature, humidity, and level of air particles remain at specifically determined levels. The machine uses the gradated glass to read its position, and then the CNC system adapts the location of all necessary parts of the machine.

"The accuracy is the most important result," says product and marketing manager J. R. Arriolabengoa. To prevent any vibrations from compromising that accuracy, the company built a literally floating room—a building within a building. There are only two companies in Europe and one in Japan with the facilities to produce gradated glass at this precision for industrial purposes. Fagor Automation has also created a thermal system to prevent any loss of accuracy related to temperature changes in the machine environment.

Meanwhile, improvements in technology such as sensors for vibration, temperature, and location allow companies to develop machines that can more easily correct themselves or notify users of potential problems, on the whole making the machines more user-friendly.

In addition, as customers demand greater flexibility to change the shape of their products more quickly, Spanish companies are focusing on creating custom-made solutions, rather than specific tools that conduct a single operation. Etxe-tar focuses on specialized, flexible machines that are developed with the specific customer in mind. Juaristi, a maker of milling and boring machines, has created systems that allow companies to carry out different processes with the same machine.

Many of these machine tool businesses reach outside Spain for the bulk of their income; export markets for Spanish companies grew approximately 30 percent in 2005 and 2006. Nicolás Correa exports about 85 percent of its products, and Etxe-tar sells crankshaft machines extensively to car companies in the United States.

"The end-user sectors are completely globalized," says Xabier Ortueta, director of the Machine Tool Manufacturers Association of Spain. "We sell in many different markets, where the production is based. For the last five years, production of many industrial products has moved to China, India, and Eastern Europe, so we move with our clients."

Environmentally Conscious

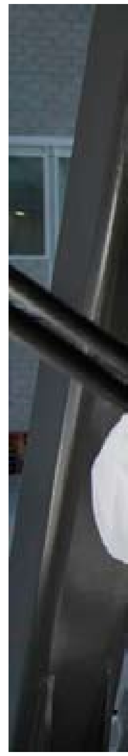
One of the most significant changes in the industry today is the heightened concern about environmental impact. In fact, new environmental standards might be considered the next stage of the industrial revolution.

As consumers seek out environmentally sustainable products, and as companies strive to reduce their impact on climate change, the machinery industry is working to meet those demands. Innovations include machines produced with less material and electricity, machines that require less electricity to operate, and machines that can use smaller amounts of lubricants and coolants in more environmentally friendly formulations. Juan José Miguel, marketing director of Etxe-tar, says the company's machines now use significantly less coolant.

The Spanish machine tool sector has taken a leading role in developing eco-friendlier machines, assisted by advances in related technologies. "New technology permits us to design machines and check the design through simulations," says Nicolás Correa's Javier Eguren. "We can be far more precise and avoid overbuilding the machines, which we did in the past to ensure rigidity and safety."

To meet international environmental standards, both the automotive and aerospace industries have been introducing new, lighter materials, including concrete or carbon fiber in place of some steel components. Carbon fiber, a composite, is especially important as a replacement for aluminum in the aerospace industry. The company MTorres, located in Pamplona, anticipated those changes in the aerospace industry and developed machinery to work with this material.

"Usually a machine places strips of material on a mold with the shape of the part that is going to be manufactured," explains Luis Izco, managing director of MTorres's aeronautics division. "The problem is that the current systems are relatively expensive, and the productivity you can get is relatively low." A cheaper and more rapid production technique is not as effective for complex shapes.



PHOTOS COURTESY OF FATRONIK

The company has developed a system that places the material on a given shape that can "make the cuts and restart on the fly," Izco continues. "With this, what you are getting is a very high deposition rate, and the number of kilograms per hour on this system is much higher than [in] conventional systems." This system also allows placement on complex shapes and parts. The first machine has been ordered by a company providing parts to the Boeing 787 and is expected to be delivered within a year.

Centered Research

In their quest for improvements and new products, companies can draw on a network of research centers that stretches around the country. These centers receive a certain amount of ongoing funding from the national government and from regional authorities, and they raise the rest of the necessary funds from specific program grants and from the companies with which they set up agreements.

About an hour outside of Barcelona, in the heart of Catalonia, the Technological Center of Manresa (CTM) focuses on materials science and the development of new materials. It opened its labs and research facilities only five years ago but has already played a key role in a number of projects. (See Focus on an Innovator for a highlight of one CTM partnership.)

One of the center's most important projects is its work with Forma 0, the government-funded research collaboration begun in 2006 that looks to adapt materials and manufacturing processes to take advantage of new high-strength steels. These tough steels have a particularly high level of a characteristic called springback, which makes them very challenging to tool.

The Spanish automobile company SEAT heads some of the lines of investigation in this consortium. "These new materials allow us to reduce weight in our products, and thereby reduce fuel consumption, while improving our crash performance," says Andre Koropp, SEAT's business manager. "We'd like to use more and more of these materials for our products, so we have to prepare our manufacturing processes to be able to employ them." The research primarily involves developing new tools and dies, particularly to optimize the hot-stamping process that is most effective with the high-strength steels.

A number of labs at CTM are devoted to teasing out different aspects of hot-stamping's effects on machine materials. "Each material behaves differently," says José Manuel Prado, director of CTM. "You need good material models to have a reliable simulation of what will happen in any given situation. One of our stronger points here is

to simulate those industrial processes." The research focuses not only on increasing the effectiveness of hot-stamping but also on finding ways to form the steel cold, despite its strength and resistance.

"It's quite difficult to predict the material's springback—it depends on the strength and thickness of the material, on the friction between the part and the tool," Prado continues. "All of this is so far an unresolved problem." And it's one that the labs are working to solve. In addition to the modeling, another project involves using physical vapor deposition to apply extremely thin coatings that increase the hardness of tools. This research has led to a spinoff project investigating decorative applications, such as jewelry or home goods covered with a deposited layer of titanium that shines like gold.

In San Sebastian, renowned for its boulevards and Michelin-starred restaurants, the research center Fatronik focuses on technologies that will have industrial market applications, such as artificial-intelligence and communication systems that integrate a variety of sensors into machines. The center has paired with companies such as MTorres to increase flexibility in big machines. It's also developing robots to assist in the manufacturing process, including a crawling robot—along the lines of a giant spider—that could, for example, drill on complex surfaces such as aeronautic wings. Such robots could speed up some functions that now depend on significantly slower manual labor.

As a way to ease robots into a number of conservative sectors, Fatronik is also working on mobile robotic platforms, a technology geared toward keeping the robot moving and not bumping into objects. Instead of using sensors to detect obstacles, the robot uses lasers, ultrasound, and a ring of infrared lights to constantly search for open spaces that it can move into. This is a relatively low-cost solution that could be used in conjunction with other industrial applications—for example, to increase safety on forklifts.

A third industrial-robotics project at Fatronik involves Spain's well-known food industry. Designed in cooperation with a research center in France, a new, patented system is one of the fastest in the world for what's known as pick-and-place tasks. The robot can stretch its long arms down to pick up a food product from one location and place it in a second at the rate of 240 cycles per minute. In one rather unusual application employed close to home in the Basque region, the robot is now being used to determine the sex of fish. The robot's arm inserts a needle into the stomach of a fish, shoots a light beam through the needle, and determines from the refraction of the light whether the fish is male or female. Females are then separated out for caviar.

"New technology permits us to design machines and check the design through simulations. We can be far more precise and avoid overbuilding the machines, which we did in the past to ensure rigidity and safety,"

PHOTOS COURTESY OF FATRONIK

"Traditionally foods were processed by thermal methods to make them safer for longer, but the heat has an impact on the quality of the foods and the integrity of the ingredients,"

Into the Kitchen

Fatronik joins other companies and research centers in taking advantage of Spain's culinary acclaim. Spanish food machinery companies supply not only the Spanish market but the global one, garnering fans as they continue innovating to meet consumer needs.

One factor driving innovation has been the change in the way people eat. "Family meals have been reduced, at best, to once a day, and that's dinner," says Josep Monfort, director of food technology at the Food and Agriculture Research and Technology Center (IRTA in Spanish). "And the average time dedicated by the whole family to that meal is about 20 to 35 minutes. Companies need to adapt to the new needs and attitudes of consumers. Ready-to-heat, ready-to-eat—those types of foods are growing in the market."

IRTA, located in a rural area near Girona, opened in 1985 with funding from the government and local businesses. Its spare white halls and cavernous rooms house machinery and labs to test different aspects of food production. In one, a huge x-ray machine allows the center to perform noninvasive tests on animals for genetics companies. Another series of rooms provides the means to evaluate drying methods. The natural light flooding the space feels cold, and it is: heat is removed from the light so as not to affect any of the heat-sensitive research.

Monfort cooperates with food processing companies in the area to create new technologies. In a recent successful collaboration, researchers at the center worked with the local company Metalquimia, which produces machinery for meat processing, to develop a new system that could vastly increase productivity in meat curing.

NC Hyperbaric's high-pressure chambers pasteurize food without heat.

PHOTOS COURTESY OF NC HYBERBARIC

Josep Lagares, whose father founded Metalquimia, explains that the current system of curing and drying meat for products such as chorizo and salami hasn't changed significantly since the time of the Romans. The ground meat is salted and infused with spices. It ferments for a short time to fuse the mass together. Then the meat hangs and slowly dries before the final product is ready to be sold.

Today, though, many people around the world buy meat pre-sliced, instead of whole. "So why don't we turn the process around? Why don't we slice it first and then dry it?" continues Lagares. "If you preslice the produce, you have a much smaller surface to dry."

Metalquimia partnered with IRTA and a local meat processor. For three years, the company has been perfecting the machinery to optimize the taste, safety, and stability of the system. "Unless you're an expert, a professional in the field, the taste is almost indistinguishable [from the standard]," he says.

The company has a small industrial machine at the factory and is putting the finishing touches on a large-scale machine that will be tested at the nearby meat producer. Once Metalquimia is fully satisfied with the results of scaling up the system, it will market the machine to its international customers, many of whom are already clamoring to buy one.

Lagares says the company's creativity began with his father, who invented machines that "simply didn't exist before." For instance, he developed a machine that would inject the meat with brine, allowing for even distribution and curing. Encouraging this type of innovation has become a systematic part of company culture.

Rather than taking advantage of the trend toward increasingly fast food, NC Hyperbaric profits from the growing interest in natural, minimally processed foods. A spinoff of Nicolás Correa, the company began operations in 2000, industrializing a heat-free pasteurization method.

"Traditionally, foods were processed by thermal methods to make them safer for longer," says technical sales manager Francisco Purroy. "But the heat has an impact on the quality of the foods and the integrity of the ingredients."

The new technique involves using extraordinarily high levels of water pressure to disrupt the normal functioning of bacterial cells. This process has been known since the late 1800s, but the technology has not been available to implement it on an industrial scale. In NC Hyperbaric's machine, food in well-sealed flexible packaging is loaded into a cylinder. Then the chamber fills with water. After the chamber has been filled, more water is pumped in, increasing the pressure. "It's like taking the final packaging and putting it very deep in the ocean—even deeper than the pressure you could find in nature," says Purroy. This pressure destroys molecular bonds in microorganisms but not the nutrients in food or the molecules that confer its distinctive flavor. The final product retains more of the fresh taste and the original nutrients than food treated with heat, Purroy says.

Improvements in steel and other materials have made it possible to scale this process up from the laboratory. One key part of the design involves tightly wrapping miles of wire around the chamber to compress the steel. Under high pressure the precompressed steel is actually in a relatively relaxed phase, which helps the vessel last longer. The company patented its designs and continues to dedicate 10 percent of its turnover to research each year. So far, only two companies are marketing this type of technology industrially, with NC Hyperbaric leading the way.

Many customers have been able to use the technology for purposes other than simple pasteurization. Seafood companies in Mississippi and Japan use the pressure to pop open bivalves such as oysters and mussels without the arduous manual labor usually required. Another seafood application involves lobsters: because their meat typically cannot be extracted without cooking, chefs who want to use lobster usually buy the meat already cooked or cook it themselves, so that it's been cooked twice by the time the dish is served. The new process makes it possible to detach the raw meat from the exoskeleton. The first companies began using this pressure machinery to extract raw lobster meat in 2005, and the product is already popular with chefs.

Opening the door to still more new products, a dairy multinational in New Zealand is using the hyperbaric chamber to pasteurize vitamin-rich colostrum, the first milk mammals produce, which cannot be treated thermally. This product is being marketed in China, where it is associated with good health.

Other manufacturers of food packaging machinery have also been able to innovate and expand in recent years. Posimat, which makes machines for filling bottles, patented a system that can automatically change from one size of bottle to another. Mespack, whose machines utilize flexible packaging, developed a system to allow the machine to automatically correct for unexpected stretching in a given material.

Ulma Packaging creates a wide variety of automatic machines and packaging technologies, from thermoforming to bagging with stretch- or shrink-film machines to sealing plastic films. Working closely with customers to develop the appropriate solutions, the company has focused on researching new films and implementing advances in 3-D design workflow, robotics, and communication or electronic controls.

"We have to stay very closely connected to film manufacturers because of innovative solutions coming in films themselves," says Francisco Etxaniz, managing director of Ulma Packaging's research center. Here, too, environmental concerns are driving innovations. As companies meet demands to recycle more and produce less waste, new biofilms are being developed that are thinner, less toxic, and biodegradable. "We've developed and patented technologies to deal with the properties of these thinner films," says Etxaniz.

As consumer products advance and trends such as concern about environmental impact evolve, Spanish companies will continue to develop new technologies to meet these ever-changing needs.

Resources

ICEX (Spanish Institute for Foreign Trade)
www.spainbusiness.com

Machine Tool Manufacturers Association of Spain
www.afm.es

Nicolás Correa
www.correaanayak.es

Juaristi
www.juaristi.com

Fagor
www.fagor-automation.com
www.fagorarrasate.com

Grupo Danobat
www.danobatgroup.com

Etxe-tar
www.etxe-tar.com

Rovalma
www.rovalma.com

Metalquimia
www.metalquimia.com

NC Hyperbaric
www.nchyperbaric.com

To find out more about New Technologies in Spain, visit:
www.technologyreview.com/spain/machinery

For more information visit:
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Focus on an Innovator

About a half-hour outside of Barcelona, a small family company has developed a new material that may help the automobile industry reduce car weight and fuel consumption.

Rovalma originated as an import business in the 1970s, supplying materials such as tool steels for dies and molds. Isaac Valls, son of the company's founder, left Spain to study for his PhD in materials science at Stanford University. During his first year, in 2000, he stayed up to date on the company. "I was taking my time, taking classes in everything that interested me," he says. "All of a sudden I detected that the industry was going to need new tool steels in three to four years." He sped through his second year in three months and returned to Spain.

The big change that Valls observed in the industry was the introduction of advanced high-strength steels. These new alloys provide a number of benefits over traditional steel alloys. Because they are so much stronger, they allow manufacturers to use less material even as they make cars safer. The resulting weight reductions can improve gas mileage and decrease a car's impact on climate change. But their extreme strength also makes these materials difficult to shape.

The high-strength steels, Valls predicted, would rapidly wear down cutting and shaping tools. "We thought that the tool material the industry has been using for the last 40 years is not going to hold up," he says. His predictions proved accurate: suddenly tools that had lasted for hundreds of thousands of pieces shattered after only 100.

With more enthusiasm than resources or equipment ("we only had one little optical microscope and nothing else," he recalls), Valls started researching alternatives. Fortunately, the research center CTM had recently opened in Manresa, not far from his family's business. In addition, the Spanish government had recently increased available research funds.

Valls began investigating what caused the failures. With the help of CTM, he determined that the cracks originated in the carbides, compounds produced by heating the tool steels to achieve the required resistance. CTM provided the equipment and a researcher able to assist in nano-indentation, using a diamond tip to create the beginnings of cracks and determine the fracture toughness of different carbides.

The key, he realized, would be a tool steel with tougher carbides, so he developed a new alloy. Selling it proved to be the next challenge, as car companies looked to their usual suppliers for solutions. "We were like a tiny mosquito or even a bacteria compared to our competitors," says Valls. "They'd been there for a hundred years—they had the market power, they had everything." But not, it turns out, the right product. Desperate to increase production speeds, automotive companies finally turned to this family-owned Spanish business. Today the new tool steel is the company's top seller.

Isaac Valls, owner and head of research at Rovalma

Then Volkswagen decided to implement hot-stamping, a process in which the new steels would be formed at a temperature high enough for the structure to change and become more malleable. Says Valls, "This is the newest technology in the shaping of sheet metal, and they were the first European company to implement it in-house."

Volkswagen was pleased by Valls's previous work, as the first die made from the company's new tool steel had already finished 800,000 pieces. The company asked him to find a solution to the problems that arose in hot-stamping. The material needed to be cooled down rapidly to maintain its form and attain the necessary hardness. Volkswagen had already changed the entire production line, installing furnaces, robots equipped to work with hot materials, and cooling systems. It came to Valls with one question: will this new process degrade the die?

After some testing, Valls reported that the dies would survive, but the painfully slow process meant the final product remained expensive. "You're getting two pieces per minute," he told Volkswagen, "and your competitors are getting maybe one. What if we produce a tool steel that can produce six or eight pieces a minute?" Volkswagen executives, he says, told him they only dreamed about reaching those numbers.

Valls partnered again with CTM. He saw that the impediment was the tool steel itself, the time necessary to transfer the heat from the high-strength steel through the die into the cooling system.

"Everyone had tried for the last hundred years to increase the thermal conductivity of hot work-tool steels," says Valls. No one had succeeded. "But my approach was totally different. I was approaching it from the fundamentals." Relying on the understanding of quantum mechanics that he'd gained at Stanford, and taking advantage of basic research conducted by other researchers (but not on tool steels), he investigated both the steel's ceramic phase and its metallic phase. He realized that one element in the alloy was compromising its conductivity. Valls created a new alloy without this element, but he needed to test it in a lab in Germany.

The lab was busy. Three weeks later, his nervousness at a fever pitch, he opened his mailbox. "I started screaming so loudly that the neighbors came out," Valls recalls with a laugh. "I said, 'You're all invited to dinner!'" The new alloy nearly tripled the best existing conductivity in tool steels. The potential productivity of Volkswagen's hot-forming process quadrupled, and the company signed a two-year exclusivity contract with Rovalma that expires in September.

Valls appreciates that the contract with Volkswagen allowed him time to prepare for the demand that will greet him after the contract expires. In addition to the factory in Spain, he's opening one in Germany. Though Valls is in no hurry to broaden applications past the automotive industry at this time, he says the aerospace industry has already expressed interest in working with Rovalma to increase productivity as well.