Silver Anniversary Paper

Toyoda Autoloom Foundry- A Look Back a Quarter Century; Decisions and Market Factors that Transformed this Automotive Giant

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ABSTRACT

This *AFS Silver Anniversary Paper* takes a look back at the original *1998 AFS Transactions* paper, "Converting from Shell to PUCB at Toyoda Autoloom Foundry."[1] Today, Toyota Industries Corporation is recognized as one of the largest and foremost innovators in automotive mobility in the world. The company was no stranger to evolution as it was established in 1926 to manufacture automatic looms to weave cloth. For a century, it has continually diversified and transformed to meet the demands of industrialization in Japan while out of respect to company founder Sakichi Toyoda, kept its original name. A quarter century ago, a plan to transform this automotive giant's gray iron engine plant from shell molding to a modern phenolic urethane coldbox (PUCB) KeyCore™ cellular manufacturing process was set in motion with a focus on several unique process innovations in anticipation of building a new modern facility in Handa City, Japan. We will look back at how several market conditions affected the Kaizen process and ultimately the adaptive evolution of this automotive casting leader.

Keywords: Toyota, Toyoda, foundry, automotive, automation, Kaizen, quality program principles, casting technology, continuous improvement, coldbox, shell core, resin coated sand, die casting, gigacasting

INTRODUCTION

The origins of one of the world's most successful and profitable corporations, can be traced back to Toyoda Automatic Loom Works Ltd, a company founded by Sakichi Toyoda in 1926 to produce looms for the textile industry. The company diversified to include a foundry to meet the needs of Japan's industrial development, Toyoda Autoloom Foundry, while maintaining its original name as a tribute to their founder. The foundry was important as the leading provider of gray iron castings for vehicles, especially its popular line of cars and trucks.

The company has achieved remarkable growth and performance in both domestic and international markets, thanks to its competitive advantages in quality, efficiency, and innovation. At the time the original paper was written, the company ranked first in taxable income among Japanese corporations in 1996, with a taxable income of 745.45 billion yen.

The original paper[1] attributed this success to the strong demand for their exports and sport utility vehicles in Japan and abroad. Moreover, they expanded production capacity in the United States, where it now manufactures more motor vehicles than it exports from Japan and is arguably the largest auto manufacturer in the world with $279.3 billion in revenue.[2-4]

One of the key factors behind the automaker's excellence is "Kaizen", which means continuous improvement. As part of "Kaizen" the co-author was assigned as lead of the CHITA project to explore, develop, and implement improvement envisioned. CHITA is a term used in the Toyota Production System (TPS) to describe a problem-solving tool that helps identify and eliminate waste in a process. A CHITA consists of four steps:

- clarify the problem;
- identify the root cause;
- take countermeasures; and
- verify the results.

The CHITA helps improve quality, efficiency, and customer satisfaction by eliminating unnecessary activities and resources that do not add value to the product or service. This approach guides operations and strategies and was key in its new prototype project at the foundry and the ultimate project to construct the new foundry in Handa City, Japan (20 miles from Obu), intended to start operation in October of 1998. The new foundry would produce 200,000 gray iron blocks per year for the 4-cylinder, 1.6-liter engines, which were used in Corolla models.

PROTOTYPE FOUNDRY IN RETROSPECT

COREMAKING PROCESS EVALUATION

The foundry had been using the shell process as the main coremaking method since the end of the Second World War. However, as the demand for more efficient, accurate and environmentally-friendly castings increased, the foundry started to explore other coremaking processes that were available in the industry. After an intensive study, the phenolic urethane coldbox (PUCB) process was selected as the coremaking process for their new foundry and, therefore, for their prototyping operation, as well.

CONSIDERATIONS FOR PUCB PRODUCTION

Siamese Production & Coresetting in a Green Sand Mold

The traditional method of assembling individual cores into a coresetting fixture and then inserting the loose core package into a green sand mold as it passes by, results in dimensional errors due to core shifts and human errors. On the other hand, placing a dimensionally stable, single-piece, modular core package into a green sand mold provides many of the benefits of productivity and dimensional precision that were achieved with the popular KeyCore Process™ offered by the Loramendi Machine Company. Therefore, the PUCB modular core package, along with the positive equipment economics, scheduling flexibility and significantly improved dimensional tolerances, enabled the foundry to make dramatic enhancements over the loose core shell concept it was replacing.

DOUBLING CAPACITY OF GREEN SAND MOLDING SYSTEM

The casting designers were able to increase the production of green sand blocks by using a Siamese coldbox core package instead of a shell core. This allowed for the placement of runners inside the crankcase cores and eliminated a long runner that was previously needed between the blocks. By rotating the core packages in the flask 90 degrees also reduced the distance between the blocks when cast, which enabled them to fit four blocks per green sand flask, instead of two. This way, they doubled the capacity of the green sand system without any significant capital investment!

MODIFICATIONS TO PUCB PRODUCTION

Once the dimensional and productivity advantages of switching from the shell coremaking process to the PUCB Siamese coremaking process were recognized, the PUCB process was examined for inherent process deficiencies. Engineering proposals were then made and evaluated for minimizing or removing the perceived process deficiencies imposed by the PUCB system.

Concurrently, the company began developing their own coreblowing machine to address the negative aspects of the coremaking process. The site for the development work on this alpha-phase core machine was their present production facility in Obu, Japan.

The Obu City prototype foundry would run production on the first of four “cells,” in what would become a full-production foundry. The prototype operation was designed to evaluate a cellular manufacturing concept for gray iron block production, based on a modular coldbox core package, as shown in Fig. 1.

This new Handa City foundry’s cellular concept was based on four identical cells, which would be built like the one being evaluated in this prototype operation. The cells were linked together by process equipment that can be utilized by all of the cells. At the same time, the prototyping operation would also evaluate and refine the design of a new type of core machine, along with the effectiveness of a newly devised pattern cleaning station, the concept of zero buffer core production and the effectiveness of a microwave corewash drying oven that dries the refractory at a temperature below the boiling point of water.

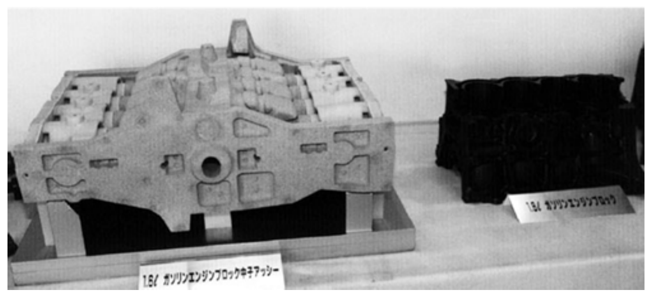

Figure. 1. The 1.6-liter block and coldbox Siamese core package cells.

Five core machines, 10 sets of tooling, four robots, one microwave oven, one Skysorter™ conveyor and one mixer, along with the necessary belts and measuring devices comprise each cell for this 1.6-liter, 4-cylinder engine design. The new Handa City plant would be comprised of four cells like the one already described. The four cells shared certain process equipment such as a pattern cleaning station, computer controlled assembled-core storage and green sand core setters.

At that time, the director, general manager, chief engineer and Project Lead/CHITA evaluated the performance of the design during the prototyping phase. The Autoloom Foundry would make modifications to the cellular manufacturing process and to the equipment, based on their recommendations. Fifteen new machines were to be fabricated, while the five machines utilized in the prototype foundry would then be rebuilt and modified for the Handa City facility.

NEW CORE MACHINE DESIGN

The coreblowing machine that was designed and built in 1992 to 1993 had some amazing features that made it stand out from other machines designed for PUCB and are worth noting:

- All five machines in the module were built identically, leading to part manufacturing versatility.
- Only one of the parts, the water-jacket core, required more than one blow tube. It had seven blow tubes to ensure uniform filling of the mold cavity.
- There were no exhaust vents in the bottom of the water-jacket tooling. Exhaust venting along the bottom of the core was done along two sides of the 24 ejector pins. The pins were ground flat on the opposing sides with 3 mm of stock removed. The flat portion on the pins extends into the exhaust plenum and, during the ejection phase, they become, in effect, self-cleaning.
- The Siamese end cores had exhaust vents on the vertical walls of the tooling, far from the blow tube. These vents were the only ones used for gassing, and they optimized the use of amine gas.

IMPROVED BLOW MAGAZINES

There were two types of blow magazines used to produce the cores in the Siamese package. One type of sand magazine was shaped like a funnel that ends with a single blow tube on the bottom. This was used for all the cores except the water-jacket core. The design guided the coated sand very effectively into the single 1-9/16-inch diameter blow tube on the bottom. The other type of sand magazine was used for the water-jacket core. It contained seven blow tubes and was constructed in the shape of a railroad car hopper, where sloped sides and ends guided the sand into the blow tubes.

In both the single and multi-blow tube magazines, the sand was metered by a load cell into a hopper located directly above the blow magazine, Sand then entered the blow magazine through a slide gate valve. This minimized the amount of coated sand entering the magazine, thereby reducing the amount of sand left in the magazine after the blow cycle. It also minimized the amount of coated sand subjected to damaging air fluidization.

Because there was no flat area in the bottom of the funnel-like magazine, and hardly any flat areas on the bottom of the other magazine, virtually all the sand introduced into the magazine was purged into the tooling during each blow.

The unique design of the blow head was a distinctive feature of the core machine that enabled all of the cores to be blown with maximum efficiency and virtually zero coated sand going to waste.

During the cycle, immediately before the coremaking operation was shut down, no additional sand was metered into the small coated-sand feed hopper, which was located between the blow magazine and the larger, Teflon-lined hopper filled by the sand coater (Fig. 2). Thus, very little sand had to be disposed of at the end of the production period. As shown in Fig. 3, the nearly empty, funnel-shaped, single blow tube sand magazine was discharged into a receiver for disposal before it was simply brushed out with a broom. The blow magazines were all Teflon-coated on the inside.

Because the blow magazines were low capacity and tapered toward the blow tube(s), there was virtually no dead space in the sand magazine. Typically, less than a couple hundred pounds of the loose uncured coated sand needs to be disposed of at the end of a shift.

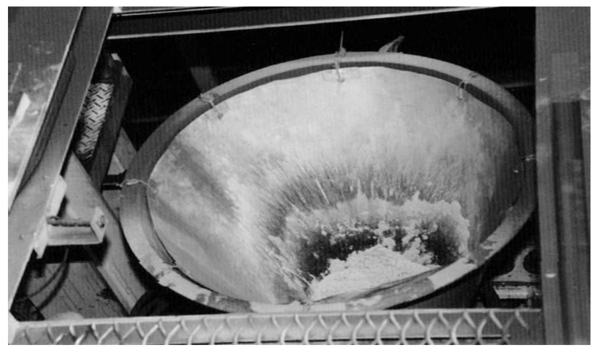

Figure 2. Teflon lining in the coated sand hopper.

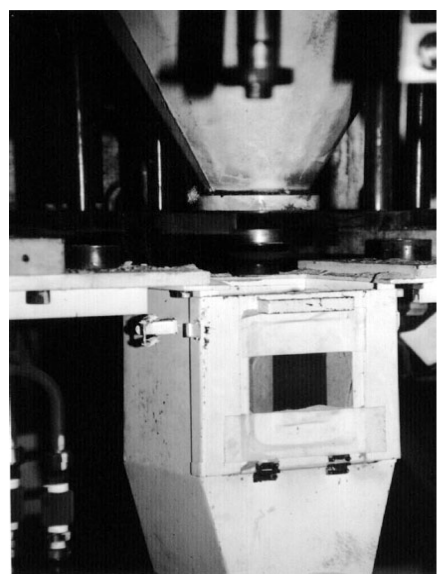

Figure 3. Funnel-shaped blow magazine discharging into waste sand receiver.

OTHER IMPROVEMENTS

Accuracy—The final core package, as well as the subassemblies (water-jacket/barrel-slab and crankcase package), were put together, glued and squeezed to result in a dimensional accuracy of within ±0.5mm. Individual cores were accurate to within ±0.2 mm. Photoelectric sensing was used to positively identify core type so that there was no mismatching of the core assemblies.

Pattern Closure—If the cope half of the tooling did not close against the drag surface to within 0.2 mm, a signal was sent to stop the machine and rectify the problem. Pattern closure was monitored in two ways: first, by a unique air-pressure sensing device fitted between the cope and drag halves of the tooling; second, by a mechanical sensor fitted to the top of the cope. If something prevented absolute closure along the parting line by more than 0.2 mm, an alarm sounded, and the machine stopped. The other four machines also stopped production until this malfunctioning condition was remedied.

Parting Line Gas Leaks—A parting line leak was monitored by a sensor between the seals and the corebox cavity through pneumatic lines incorporated into the cope half of the parting between the core cavity and the seal. If a leak was detected, based on a pressure drop, a warning was given.

Environmental Improvements—The manufacturing area was quiet enough to eliminate the need for ear plugs. Odors in the area were controlled so that protective masks were not necessary.

Amine Gas Generator and Scrubber—the company designed and built its own vaporizer generator. Carrier gas temperature was 85C (185F) and purge air was heated to 90C (194F) by the generator. Figure 4 shows how the amine gas and purge line was insulated to maintain temperature and prevent amine fallout.

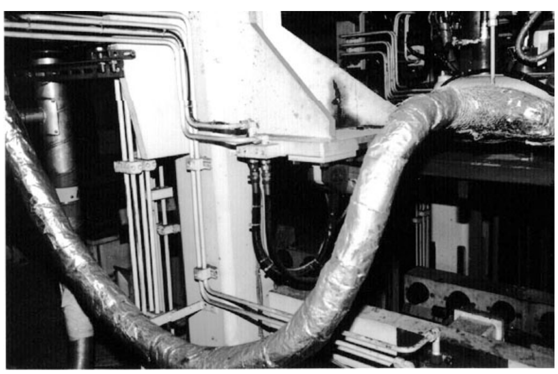

Figure 4. Gas and purge air lines showing the insulation around the delivery line.

Personnel Reduction— One person operated the entire prototype manufacturing cell during production. Other people, with special expertise, assisted the single operator controlling the production in the cell. These people were assigned various tasks such as correcting core machine malfunctions, filling the refractory coating tank, re-moving tooling from the back of the core machine and bringing it to the cleaning station, general maintenance, etc. The accumulated time input from these other people per cell generally did not total eight hours per shift, meaning that the cell operates with a total labor input of two people.

COREMAKING PROCESS OVERVIEW

CORE MODULE ASSEMBLY

One full-time production worker was assigned to the core module package assembly area (CMPAA), shown in Fig. 7. The CMPAA was a closed, air-conditioned structure located next to the crankcase subassembly room, which housed robot #1 and the crankcase stacker. This worker personally inspected each core, as well as the water-jacket/barrel-slab subassembly and the package of the four Siamese crankcase cores, both of which were robotically assembled.

As the person in the CMPAA places cores into the module assembly fixture, each core was visually inspected to ensure its quality (Fig. 5. After all the cores were in place, the fixture closed and a shell-coated sand breather core set into the package, as shown in Figure. 6. The package was then squeezed together to a predetermined dimension, and the hot-melt glue was injected into the package.

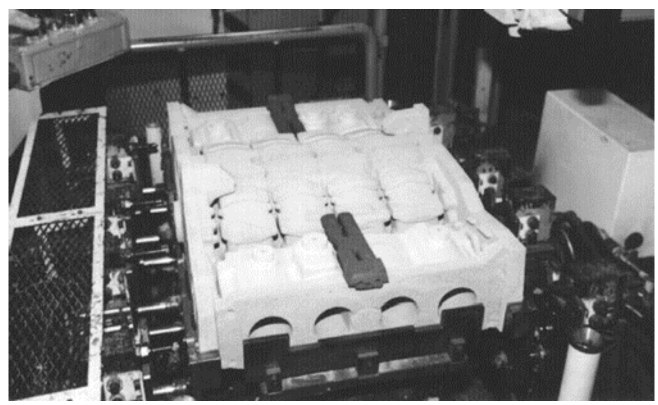

Figure 5. Setting the barrel-slab/water-jacket subassembly into the core module.

Figure 6. Core package with gluing fixture drawbacks in place against the outside of the assembly. Note the shell breather core on top of the package.

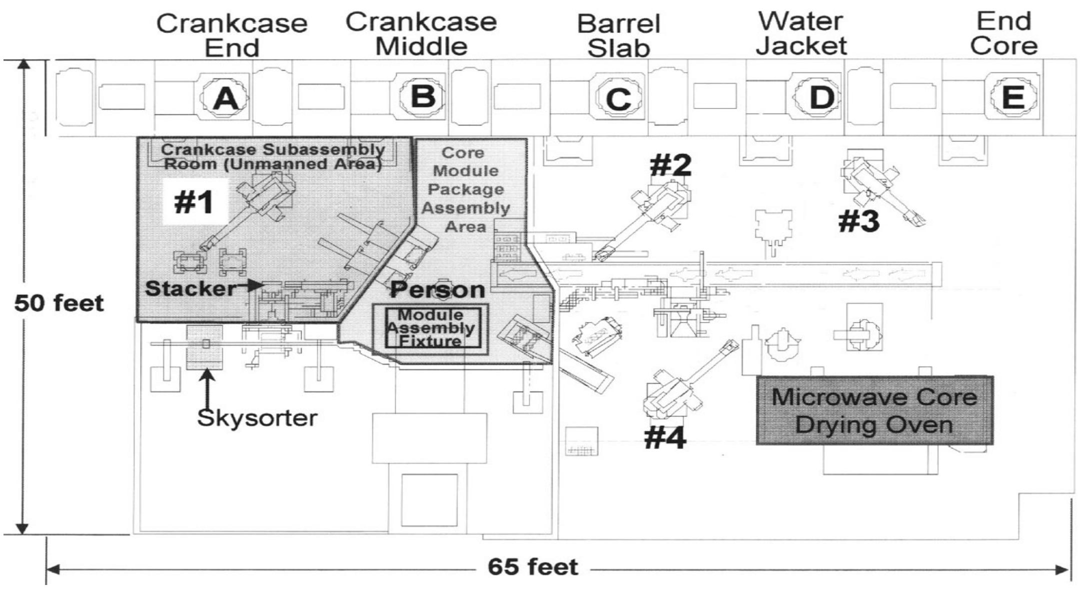

Figure 7. Core module package assembly area and prototype plant.

If a core failed to meet the quality standard, all machines were immediately stopped until the badly functioning machine was inspected and repaired by the assisting personnel on the team. After repairing the source of the problem, that core machine, alone, completed the cycle. After completion of the makeup cycle, all five machines go back into their coordinated 58-second cycle.
As shown in the plan view (Fig. 7) of the prototype module, except for the satellite tooling wash station, the entire manufacturing area was contained within a space of 18 x 14 meters (65 x 50 feet). Amazingly, the work areas remained uncongested, even though the space contained the assembly/control center, a subassembly station for joining the Siamese crankcase cores, five core machines with quick-change tooling turntable and aisleway access, four robots, a corewash station with microwave drying oven, and all the belting, transfer tables and assembly devices.

As seen in Figure 7, the five core machines were lined up across the top of the plant layout. The first two core machines, A and B, produced Siamese crankcase cores weighing 6.7 kg (26.8 lb.) each. Core machine A made the end crankcase core. Machine B made the middle crankcase core. Robot #1 serviced these two machines shown in the top left of the plant diagram.

The crankcase cores, after being robotically removed from the two core machines, were stacked, glued, and squeezed to a predetermined height, and stored in an unmanned area. After a stack of four cores had been assembled, glued, squeezed, and measured for dimensional accuracy, it was transferred out of the crankcase subassembly room. It was then horizontally oriented and conveyed to the staffed CMPAA by a unique monorail conveyor known as the Skysorter.™

The system was a small, induction electric-powered crane made in-house (Fig. 8). It traveled on a monorail to move the glued package of four crankcase cores from the crankcase subassembly room to the CMPAA.

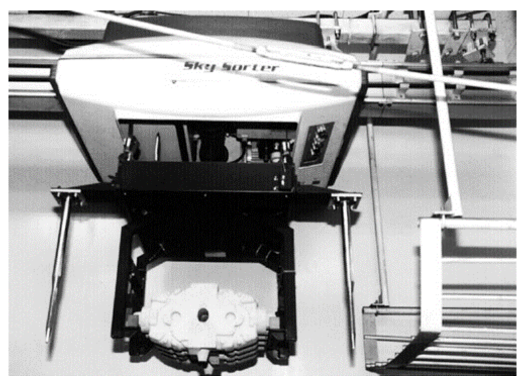

Figure 8. The electric-powered crane for moving the crankcase subassembly from the crankcase subassembly room to the CMPAA.

Machine C made the barrel-slab core and was served by robot #2. Machine D produced the water-jacket core and was also served by robot #2. When the water-jacket core was removed from the tooling by robot #2, it was placed onto a location fixture for defining by robot #3.

Machine E produced the end core and was served by robot #3. When the end core was removed from the tooling, it was placed onto a conveyor belt and traveled directly into the CMPAA. Besides handling the end core, robot #3 was equipped with a drill-like motor mounted on the side of the robot's arm for definning the water-jacket core. The motor twirls a flexible, spring-tipped steel rod over the inside and outside surfaces of the core, along the line where there might be a fin (Fig. 9). The flexible, spring-tipped rod showed little sign of being worn after extended use.

Robot #2 placed the water-jacket core (after definning) onto the barrel slab where it was glued, squeezed, and measured. Then the water-jacket/barrel-slab subassembly was indexed to wait for robot #4 to dip it into the coating tank.

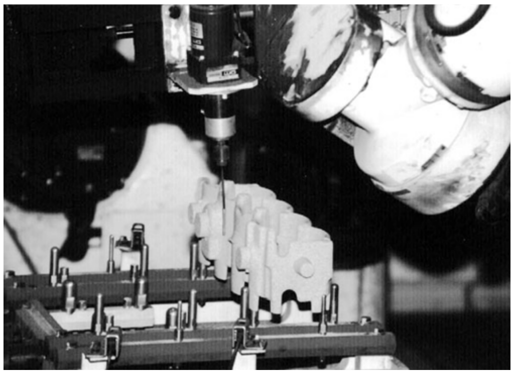

Figure 9. Definning the water-jacket core on the holding fixture with the robot-manipulated, drill-like spring-tipped steel rod.

The refractory coating was especially formulated from ceramic, talc, and water for use in the microwave drying oven. After dipping and a short drain time, the subassembly was placed into a microwave oven for a six-minute drying cycle. After microwave drying of the refractory coating, robot #4 placed the subassembly onto a drilling station fixture. Eight 3-mm diameter holes were drilled in the bottom, through the slab part of the barrel slab and up into the water jacket. Then, holes were drilled at right angles to the holes that had been drilled through the water-jacket freeze plugs.

After drilling, the subassembly was transferred by robot #4 onto a conveyor belt for delivery to the CMPAA. After visual inspection, chaplets were placed into the water jacket. Then it was placed into the module assembly fixture for gluing and squeezing, as part of the modular core package.

Each machine must cycle twice to complete the finished modular package. It was necessary to cycle all five machines twice, to make a complete modular core package. Even though five core surfaces produce each casting, the Siamese core configuration produces two castings simultaneously. Requireing ten cores to make the two castings, or five core surfaces, for each casting.

CORE STORAGE AREA

After assembly, the complete 46-kg core package was shuttled out of the assembly room and placed onto an electric car for transfer to the computer-controlled storage area shown in Figure 10. There were two computerized storage racks used to store the packages until needed by the green sand molding line. The two racks were seven compartments wide by seven high. Since the modular packages were always handled in pairs, beginning from the time that they were removed from the CMPAA, they were stored two per compartment in the storage racks. Thus, if the storage racks were to contain only modules for the 1.6-liter engine block, the two racks would contain l 96 core modules, or enough cores to make 392 of the 1.6-liter gray iron castings when delivered to the green sand molding line.

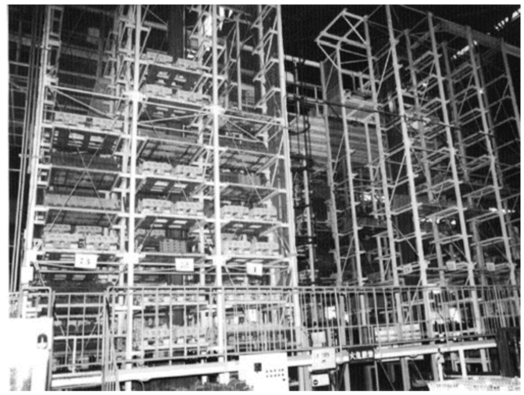

Figure 10. The computer-controlled storage area.

It was apparent that this modular production design did not contain any buffer (emergency bank of cores held in storage) that can be utilized to maintain production of the modules, in case of any type of core supply interruption. This was true in the case of the individual core modules, but not exactly true in the case of the green sand molding line. Since each of the ninety-eight core storage cells contained two complete Siamese-type packages ready for transfer to the green sand molding line, the green sand molding line was, in effect, buffered via 196 core packages. If the entire storage volume was dedicated only to the 4-cylinder engines, there were enough core packages to produce 392 engines stored in the computerized storage racks.

When the core package was removed from storage, it was transferred, again by an electric car, to the green sand mold coresetting fixture and placed into the green sand mold.

SPECIAL ASPECTS OF OPERATION

SAND HANDLING

Raw sand was transported into the plant via pneumatic transport. The sand temperature was controlled at 25C (77F) in the summer and to 35C (95F) in the winter, using a spiral transport fluidized bed heater/cooler. A Klein vibratory mixer coated with a blend of 20% new and 80% reclaimed silica with a grain fineness number of 60. The stationary mixer did not shuttle over the hoppers. Instead, a dump pan received the coated sand from the mixer and traveled to the appropriate machine hopper, where it inverted and discharged its load into the hopper above the machine. The mixer’s batch cycle was 25 seconds with a batch size of 23 kg. Mixer bowl cleaning took place weekly by removing it from the motor and burning the resin buildup from inside the bowl. During this prototyping phase, the binder level was high at 1.9% based-on-sand weight. The ratio was offset so that, by weight of the sand, it was 1.0% resin part I and 0.9% urethane part II.

SAND RECLAMATION AND REUSE

Sand reclamation plans had not been finalized. At the time it was proposed that the coldbox core package be scalped out of the green sand; the core sand was particulated and then thermally reclaimed by the preferred raw sand supplier. The sand supplier was to blend the reclaimed sand with new sand at the ratio of 80 parts reclaimed to 20 parts new. The blended sand was to be shipped back for use in the coldbox core process. The water-jacket core was always made with only new sand. If there was an excess of PUCB-coated sand being sent from the foundry for reclamation, the supplier would, after reclaiming it, return it to the company shell sand coating plants, or coat it in their own shell-coating process.

MICROWAVE DRYING & REFRACTORY COATING

The microwave drying oven, Figure 11 was a unique device that consisted of six distinct sections within the microwave enclosure. Each section was, in effect, partitioned from the core package in front of it and behind it by a steel plate that was about the height and length of the core. As the core package traveled through the oven, it was indexed in six equal steps of 9.8 seconds each. During this movement, the microwave energy was, in effect, turned off while it shifted between the microwave compartments. The temperature of the corewash evened out during the transfer between the compartments. Because the microwave energy was, in effect, turned off during these transfer periods, the coating's temperature did not become overheated; nor did it develop hot spots during the drying operation.

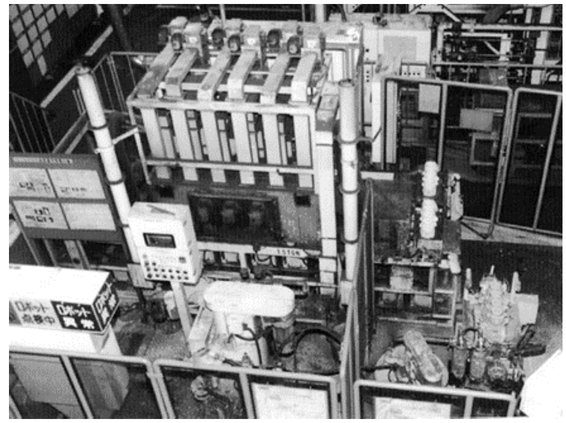

Figure 11. Microwave barrel-slab/water-jacket subassembly drying oven. Corewash dip tank located in front of and to the right of the oven. Note the two cores in front of the oven. The lower one is about to enter the oven, and the one above had just been cycled back. Cores can be seen through the screened opening in the middle of the oven.

The assembly was exposed to regulated microwave energy from three 1.5-kW magnetron tubes in each compartment, for a total of about 10 seconds, as it traveled through the oven. The microwave energy evaporated the water from the mica/ceramic graphite-free coating (carbon-based coating could not be used because of the microwave drying—the microwave heats up carbon-based materials), with a minimal temperature increase. No steam evolved to weaken the coldbox resin bond during its travel through the oven. The core surface temperature upon exit from the microwave oven was 45C (113F) and could be handled without gloves, if necessary. Because the drying process temperature never approached the melting point of the hot-melt adhesive, which was 120C (248F), there was no risk of adhesive failure. Since there was no odor or toxic materials expelled from the coating during the drying operation, the oven was open to the work area, and the exhaust from the oven was simply discharged into the atmosphere.

PATTERN CLEANING STATION

The company-designed and built pattern-cleaning station had performed well during the prototyping phase of converting from shell to coldbox. When the 2200-lb pattern was delivered to the station by forklift truck, it was moved forward on a roller conveyor and into the clamshell-like device, Figure 12. The tooling handle attaches to the pattern. It then separates the cope from the drag. After moving into the cleaning room, it holds the tooling in a nearly vertical position, tilting it forward slightly so that the water drains out of the interior pockets.

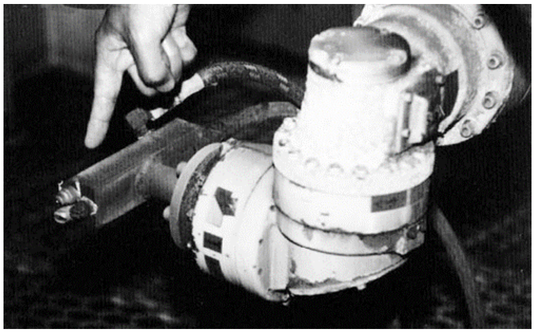

Figure 12. The transport-handler opens pattern.

A robotic-manipulated spray head emits high pressure (150 bar or 2250 psi) hot water (90C/194F) following a computer programmed path. The robotic arm shown in Figure 13 was equipped with three different orifices. One blasts the surface with a pencil-like stream of water, another sprays a fan pattern and the third, a conical pattern. The arm and the spray head were programmed to articulate over the surface of the tooling and to take special care to ensure that the vents and channels behind the vents were thoroughly cleaned.

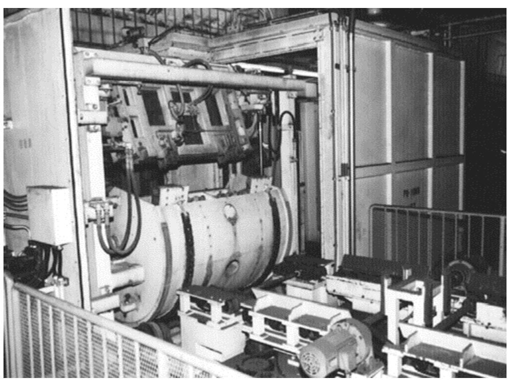

Figure 13. Three orifices, mounted on the robotic arm, are used to clean the patterns.

Clean tooling was especially important to continuous coldbox production, and the performance of the pattern-cleaning station had been closely watched. It would be transferred, virtually without any modification, to the new plant and centrally located in the vicinity of the four manufacturing modules. Since the automatic tooling cleaning station had been found to cycle the pattern back to the core machine within 15 minutes (8 minutes for cleaning and 7 minutes for forklift transfer), it would have more than enough capacity to clean all 20 of the coldbox tooling sets, each shift.

Each machine had two sets of tooling. One set would be in operation and the other would be stored on the back of the core machine, either waiting to be cleaned or having already been cleaned, waiting to be loaded onto the core machine. Each machine was equipped with a turntable to facilitate quick removal of the tooling from the machine.

A FUTURE UNEXPECTED

In the 1990s, the company was heavily invested in the shell core process for casting iron and aluminum engine components.

Overall, the Handa City casting factory was a strategic move to modernize manufacturing capabilities and support the transition to more sustainable production methods. The initial purpose of the CHITA project was to advance the development of thin-walled cast iron cylinder blocks with enhanced dimensional accuracy and increased productivity. This was achieved by transitioning from the traditional shell core process to the phenolic urethane cold box (PUCB) method. The project aimed to triple productivity and improve the quality of castings, aligning with the company's broader goals of innovation and efficiency in manufacturing processes.

The project drew inspiration from international visits to plants in Spain, Germany, and Ford's Windsor-Canada plant, adopting advanced techniques to improve core and casting processes. As a result of these visits the CHITA project leader learned about key core systems and cold box.

The new casting factory planned for Handa City in 2000 was part of efforts to enhance casting processes and improve production efficiency. This facility was intended to support the transition from traditional shell core methods to the phenolic urethane cold box (PUCB) process, which offered better productivity and dimensional accuracy. The factory was designed to implement advanced cold box technology, which was more energy-efficient and environmentally friendly compared to the shell core process. The new facility aimed to triple productivity by adopting the PUCB method, aligning with goals of innovation and efficiency.

The precision, modular core production technique had been thoroughly evaluated. It provided valuable information about a relatively low-cost way to produce a high-quality core package with predictable dimensions and outstanding casting properties. The innovative approach to modular core production and cellular manufacturing provided information that would undoubtedly serve as the basis for a totally resin-bonded core and mold package to build on as they approached the new foundry in Handa City in 2000. While the CHITA project lead advocated for adopting cold box cores, the large number of existing shell machines limited this transition. While the test results were positive and convincing, both internal obstacles mounted as external market forces challenged the benefits of the plan forward. The transition was not immediate or complete. A large number of existing shell machines initially limited the full adoption of cold box technology.

The factory's operations were in line with the company's environmental vision, focusing on reducing energy consumption and emissions.[5]

MARKET FORCES

Market forces prompted changes in casting processes from 1995 to 2020 in the automotive industry and were driven by several key factors:[6]

Fuel Efficiency—a major driver was the need to improve fuel economy. Reducing vehicle weight significantly enhances fuel efficiency, with a 10% weight reduction potentially improving fuel economy by 6-8%. This led to a shift from traditional heavy materials like cast iron to lighter alternatives such as aluminum and magnesium alloys.

Advanced Materials—the use of lightweight materials like high-strength steel, aluminum, and composites became more prevalent. These materials not only reduce weight but also maintain structural integrity, contributing to better vehicle performance and efficiency.

Die Casting Innovations—the diecasting process was adapted to produce lightweight, high-performance components, particularly for electric vehicles (EVs). This method increased production efficiency and reduced costs, making it a critical part of modern automotive manufacturing.

E-mobility—the rise of electric vehicles (EVs) required different manufacturing techniques due to their distinct design and construction needs. Electric vehicles typically use fewer parts than internal combustion engine (ICE) vehicles, simplifying assembly processes and reducing labor costs.

Sustainability—there was a growing emphasis on reducing the environmental impact of manufacturing. This included using recyclable materials and minimizing energy consumption during production, which diecasting processes helped achieve.

Regulatory Requirements—stricter emissions regulations pushed manufacturers to adopt processes that support the production of lighter, more fuel-efficient vehicles without compromising safety.

By the early 2000s, the company had largely switched to aluminum heads/blocks. Cylinder blocks transitioned to almost 100% die casting, eliminating the need for cores. Cylinder heads mainly used low pressure casting, with some large diesel heads using tilting gravity casting with reduced or no cores. As the company shifted towards aluminum die casting for cylinder blocks and heads, the need for cores in these components decreased.

The market shifted quickly to fuel efficiency and electric vehicles in the late 2010s. China began leading the transition to electric vehicles, pushing forward the era of gigacasting. The early 2020s led to the development of gigacasting—using massive die-casting machines over 10,000 tons to produce large structural components. With its preexisting base of automaking technology and equipment and its broad model lineup, the company was differently situated from younger companies. It needed to change quickly, and they did. They showed off a prototype of their new gigacasting equipment that can produce one-third of a car body in about three minutes, a development that will be key to its plans to ramp up electric-vehicle production profitably in the coming years. This gigacasting prototype cuts production time from hours to minutes.[7] Today, the company aims to exploit such advances to halve production processes, plant investment and manufacturing preparation lead time, all to aid in their quest to sell 3.5 million electric vehicles a year by 2030. In Figure 14 a single die-cast piece will make up the entire rear third of the vehicle chassis. This is normally built from 86 parts in a 33-step process that takes hours.

The company built its first gigacasting prototype in September 2022. While the heavy molds initially required as much as a day to swap out, this has been cut to 20 minutes by minimizing the number of parts that need to be detached. This setup does away with conveyor belts, enabling the plant's layout to be changed faster and cuts down on investment. The goal is to halve assembly time from around 10 hours now.

Figure 14. Gigacasting will be used to make the front and rear sections of the new electric model due out in 2026.[7]

Alignment—the CHITA's project innovations supported broader environmental strategies, such as the Environmental Challenge 2050, which aims to achieve a net positive impact on society by reducing CO2 emissions and promoting sustainable practices. Overall, the CHITA project contributed to company environmental objectives by enhancing production efficiency, reducing energy consumption, and supporting the transition to more sustainable materials and processes.

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