Mazda overhauls rotary engine plant in Japan

"In 1973, there were 14 automobile manufacturers in the world that had joined the Rotary League," said former **Mazda** chairman Kenichi Yamamoto, the rotary wizard who now serves as the company's Honorary Senior Advisor. "One by one, they dropped out of contention to make this remarkable engine a reality."

Leaving only Mazda. The Hiroshima-based automaker and a small number of its faithful suppliers alone possess manufacturing and material technologies for series production of the Wankel-type rotary engine. There may be a few other specialists who undertake the venture, but certainly not for automotive application.

Still sought by Japan's diehard enthusiasts, the rotary engine has been produced in a trickle, at best, from the company's Ujina factory complex. Official records cite an aggregate production of the third-generation RX-7 over its 12-year life (continued to August 2002) of 68,531 units. Only a few hundred have been produced in the last years of the model run.

Now, Mazda is gearing up to produce 60,000 units of the new RX-8 every year. The rotary plant at Ujina has been completely overhauled, renovated, and largely digitized. Mazda production engineers fondly call the plant, "Space-battleship Yamato."

The original Yamato was a behemoth of a battleship, with a mass of 72,809 ton (66,051 t), and was 263 m (864 ft) long and 38.9 m (128 ft) wide. Built toward the end of World War II, it was too late and too cumbersome in the face of rapidly changing war technology, and as such succumbed to a barrage of American airborne torpedoes. Enterprising animators "discovered" the great ship in the depths of Okinawa Sea, salvaged it, and built a space-battleship around its hull, giving birth to the Space-battleship Yamato, a popular TV series.

Mazda engineers point to a row of freshly painted machines whose origins go back to the heyday of Mazda's



The colored pieces of this built-up sand mold of the side housing are for port openings.



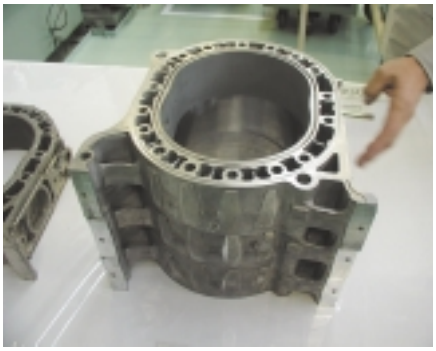
Automated machining of side housings is one of the first steps in the production process.



For RENESIS rotors, molten metal is poured centrally versus the previous 13B-REW's pouring from the corner (left). Uniform metal distribution and more precise rotor balance are achieved.



The aluminum rotor housing is cast around a steel sheet-metal insert. The process is now digitally controlled.



The new SIP process and precision machining of the trochoid housing allow chrome plating without masking.

"rotarization" era in the 1960s and '70s, when the ambitious company turned almost every Mazda car, as well as one truck and one small bus, to rotary power. This tooling, like none other, was dedicated to production of the rotary engine.

Digitally modeled based on Mazda's veteran rotary craftsmen's skills and know-how, the manufacturing facilities have been updated and rebuilt to incorporate the latest numerical control technology. The plant has been transformed to a space battleship in its own right, launching the latest Rotary Rocket, the RX-8.

A plant like no other, for an engine like no other, the Rotary Plant produces many of the major components of the new RENESIS engine in-house. The engine, which inherits the 13B two-rotor engine family's internal dimensions and geometry, is a new design with few carryover parts. Mazda casts, machines, heat-treats, plates, and finishes the engine's major components, including die-cast aluminum rotor housings, cast-iron side and intermediate housings, and cast-iron rotors. The steel eccentric shaft forging, equivalent to the conventional engine's crankshaft, is supplied by an outside specialist, with Mazda machining and finishing it.

A rotor housing construction process called SIP (sheet-metal insert process) has been employed in Mazda's rotary engine since the mid-'70s. The aluminum rotor housing is cast around a sheet-metal insert with a jagged surface that ensures tight bonding, much like cast-iron liners in a conventional aluminum cylinder block. The Wankel rotary engine's triangular rotor follows the complex curves within the inner working surface of a peritrochoid chamber, whose shape is rather like a sectioned silkworm cocoon. The peritrochoid profile must be precisely shaped. Previously, a mechanical machine tool using the copying-grinder principle was employed. For the new RENESIS engine, Mazda designed a CNC (computer numerical control) five-axis grinding machine that improves machining precision by 60%, contributing to the engine's gas-tightness.

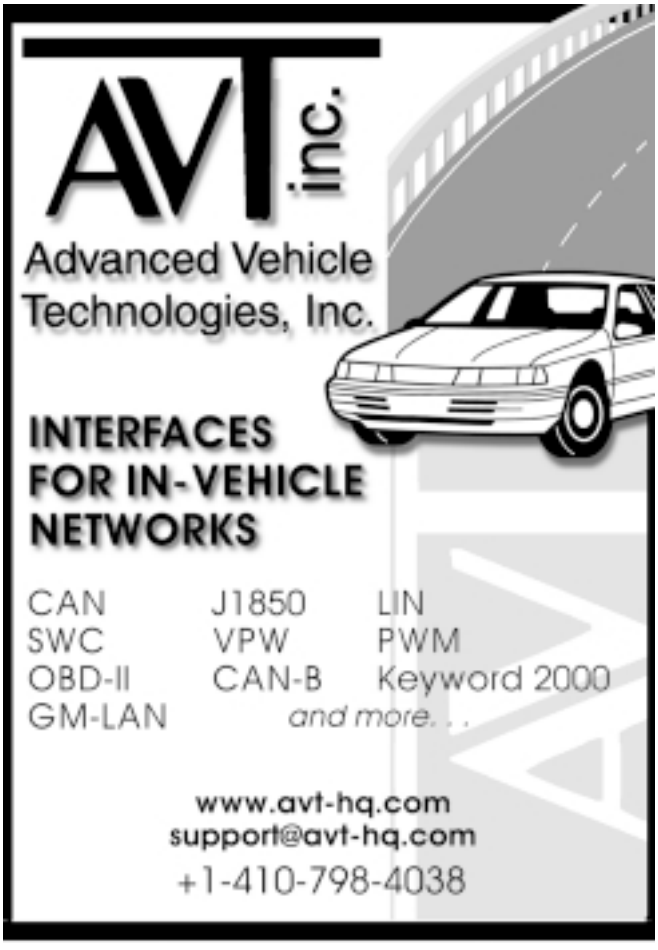
The machined sliding surface is applied with hard "pin-point" porous chrome plating with micro channels. The process involves the application of reverse voltage after chrome plating so that



Much of the tooling in the plant is 30 years old, but it has been modernized for production of the RENESIS engine.

miniscule channels are etched. After honing, reverse voltage is again applied to create pores at the channels' intersections. Pore and channels retain lubricating oil.

The cast-iron rotor is one of the two heaviest rotating components in the rotary engine. The other is the eccentric shaft, whose motion is nicely balanced compared with the rotor's planetary motion. The RENESIS rotor has shed 5% of its mass versus the previous 13B-REW twin-turbo engine, and now has a mass of 3.9 kg (8.6 lb). That is still a hefty mass, but the rotor revolves at a third the speed of the eccentric (output) shaft, so at the high-power RENESIS' peak revs of 9000 rpm, it revolves at only 3000 rpm.



Circle 269



Fitting the intermediate housing requires skill and experience, the craftsman shown performing a wiggle and fit process.

Still, the lighter the rotating components, the lower their inertia and the better the engine's responsiveness, which improves fuel economy. Molten metal previously was poured into the mold between apices of six rotors, three stacked in two pairs. In this casting method, molten metal cooling temperature is not even, causing irregular density in the casting. For the RENESIS rotor, molten metal is poured into the center of the mold of three rotors, delivering a more even weight balance and cast density.

Each apex-seal groove corner of the rotor is induction-hardened. A "pin-point" induction-hardening device was developed by a Mazda heat-treatment expert, winning the government-sponsored Award of Excellence in 2002. The new system allows full automation of the process and ensures stable hardening.



The engine is fired and run at 4500 rpm. A glass of wine atop the engine provides a measure of smoothness.

For the rotary engine, gas sealing has been by far the most crucial technological challenge in design, development, material, and manufacturing. The late Felix Wankel was an expert in gas sealing, and realized his dream of a pure rotational internal-combustion engine. Mazda relies on its former subsidiary, **Micro-Techno**, now spun off and renamed **Kolbenschmidt KK** to supply apex and corner seals.

The rotary engine's gas seals consist of apex and corner seals in the three apices of the rotor, and side seals and a newly added blow-by cut-off ring seal on each side of the rotor. Previously, the side seal was an arched and rectangular-sectioned piece with a thickness of 0.7 mm (0.03 in). The new engine's side-port configuration allowed significant enlargement of both intake and exhaust port opening areas. Earlier in the development stage, Mazda engineers experienced frequent breakage and "swallowing" of side seals when they traversed over the ports. A new keystone seal 1.2 mm (0.05 in) thick at the top is adopted to solve this problem.

The keystone seal has a trapezoidal section, thicker at the top and tapering down at 4.5° in its 3.5-mm (0.14-in) height. Machining three trapezoidal-sectioned grooves on each rotor side was another challenge to the manufacturing team. The cutting tool is subjected to lateral force in addition to vertical because of the tapered groove. A new CNC machining system was developed in-house with improved cutting tool rigidity. The tool cuts 0.06 mm (0.002 in) in each of 78 travels (it moves arched sideways in a reciprocating movement), delivering a groove 4.68 mm (0.18 in) deep to accommodate the seal.

The whole rotor and eccentric shaft assembly is balanced. The rotor's sides must be gas-tight; therefore, the previous method of balancing by milling is no longer possible.

The RENESIS engine's major internal components are hand-assembled in the "Rotary Room" within the plant, minus external systems including intake, exhaust, and electric systems. It is a glass-walled "clean room," separated from the machining and assembly area. A small, highly trained workforce selects and fits gas and oil seals in rotors, and water seals to side housings. The Mazda rotary craftsmen put together the engine proper. The completed engine is then transferred to the overhead conveyer system, where external systems are installed.

The function assurance system is employed to digitally check and ensure uniform compressions in the three working chambers of each rotor housing via pressure sensing and sonic-wave measurement. Each engine is fired and revved up to 4500 rpm for a final test.

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