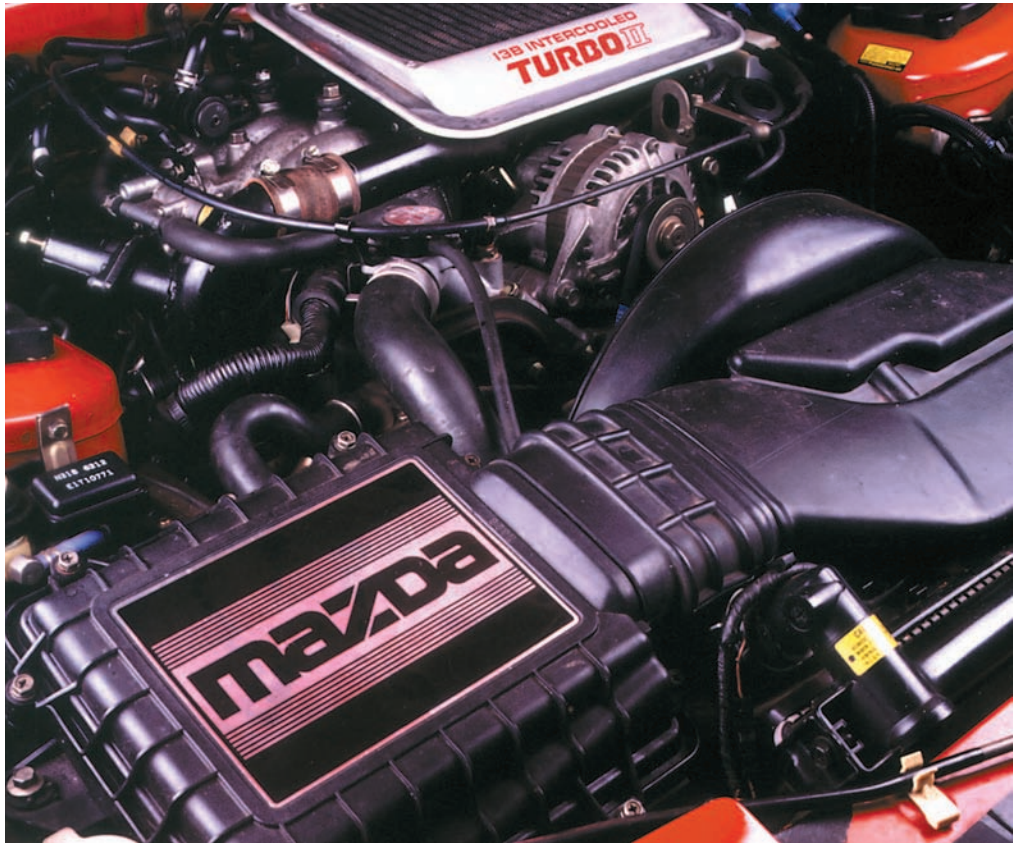


# Rotary Engines



Unfamiliar shouldn't mean impossible. Here's how to check a Mazda rotary engine for basic mechanical integrity.

**A**n engine most of us have always found interesting, but (if you're like me) haven't worked on enough to know as well as our interest would incline is the Wankel rotary used on Mazdas, mostly in recent years their RX-7 sports cars. The last new ones imported were for model year 1995, and rumor has it Mazda's major partner, Ford, wants to engineer the disappearance of the unconventional rotary engine. But who knows anything about corporate policies? That was also the last year before OBD-II, which might account for it.

The question I pursued was how to determine what to do if you get an RX-7 in your shop that runs poorly or not at all but the fuel and ignition systems seem to work normally. When is a Mazda-Wankel rotary mechanically worn out or broken? When should you swap that block — if that's what you call the... er, engine case — for a rebuilt? I've heard of Mazda rotaries still running fine after more than 300,000 miles, and you probably have, too. But we've both heard of them locking up or spinning airlessly far short of 50,000. What tests can we do to tell whether we have a 'keeper' or a 'heaver' on our hands?

A good way to find out something you don't know is to ask someone who does, so I turned to David Atkins of Atkins Rotary, way out there in Puyallup, Washington State. Atkins has worked largely on Wankels since 1976, races them and builds them for boats and airplanes, so he knows most of their strengths and weaknesses. He also rebuilds or remanufactures the engines from cores he gets in trade. It's hardly surprising that he's a rotary nut, running a Mazda rotary drag racer with shift points at 8000 and 10,000 rpm.

## How's It Work?

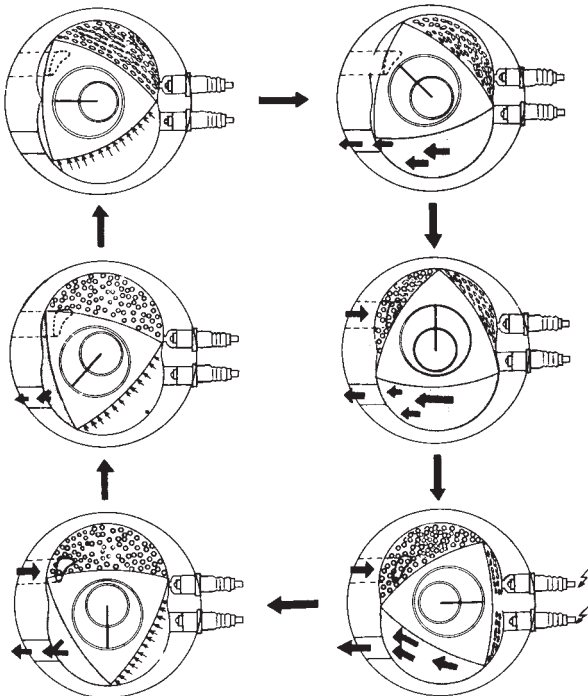
If you look at sequential pictures of a Wankel engine combustion cycle, it seems like a puzzle. If you look at one open on your bench and turn the eccentric output shafts or the rotors, it's all clear and obvious. Explaining how it works in words is about as awkward as explaining how a differential works. But I'm dumb if not chicken, so let me take a stab at it, anyway. I assume, of course, anyone reading this already knows quite well how an ordinary piston-and-crankshaft engine works.

The RX-7 engine uses two of the chubby triangular rotors you see, and they're out of phase with one another by 60 degrees to maintain dynamic balance and to keep the power strokes equally separated.

You can build Wankel rotaries with any number of rotors (though four is the most I've heard of), but if you understand how a one-rotor engine works, you understand the concept in the same way that, if you understand how a one-cylinder engine works, you understand the basics of multicylinder powerplants. More cylinders or rotors let you smooth out the power delivery somewhat and change the shape of the engine to fit in a car somewhat better, but each cylinder or rotor works the same way.

The rotor, a fat equilateral triangle in cross-section, turns in an "waisted two-node epitrochoidal" chamber, the curved surface of which corresponds to the path of the apex tips of the rotor as it turns. This keeps the three combustion spaces between the rotor and the chamber separate from one another at all times. As each of the three spaces goes around the chamber once, it expands and contracts twice, allowing it to go through each of the four engine cycles: intake, compression, power and exhaust, as it uncovers and then covers the corresponding ports. Since there are three chambers per rotor, there are three power strokes from that rotor per complete rotation. There are also three power strokes from the other rotor, sixty degrees out of phase with the one we can see, making six power strokes for the engine complete.

That sounds like it ought to make fantastic torque, six power strokes per revolution, just what you'd have with a twelve-cylinder engine. But it's not. The rotors are not the output or eccentric shaft. Let's see how the torque developed by the combustion burn gets from that fat triangular rotor to that wobbling output shaft.



In the center of the rotor are two elements: an internal gear and an internal bearing. The gear engages the teeth of a stationary gear bolted in fixed place at the center of the engine. The eccentric output shaft main bearings journals fit through the bearings in the middle of these fixed gears. The stationary gear has exactly two teeth for every three on the inside gear of the rotor, 34 for 51 in the example in the photos. There is no great load on these gear teeth, but they serve to keep the rotor aligned so its movement will keep the apexes moving exactly along the epitrochoidal (See? It just trips off the tongue with a few mentions) surface of the chamber.

Notice this, though: As the rotor turns clockwise in the curved chamber, the bearing in its center describes a faster clockwise movement, turning the eccentric shaft three times for each single orbit of the rotor. You've already noticed one more thing, I'm sure: That means that while the rotor may not be turning particularly fast in the chamber (a third the output shaft speed), the output shaft is turning quite fast in both its main and eccentric journal bearings. These bearings between eccentric and the stationary gear bearings and between the rotor and the eccentric 'crank' journals are the most critical fits in the engine, making the importance of regular clean oil obvious.

Balance shafts on the eccentric can perfectly offset the offset weight of the rotors, insuring the Wankel's surprising smoothness. What's more, because of the triple-multiplied speed of the output shaft, each power stroke lasts for 270 degrees of output shaft rotation, 90 degrees longer than the equivalent for a piston engine. So we have two separate and significant sources of smoother torque delivery.

Fuel and spark work basically the same way as on piston engines, so we won't go through those here. Take note that each rotor has two spark plugs to avoid the problem that at some angles of spark advance the chamber is divided by the narrow point of the housing — the 'waist' — masking part of the mixture from flame propagation. Because there is no equivalent of crankcase splash below the piston rings to lubricate the cylinder walls, the engine also includes a device to add some oil to the rotor chamber during operation, the volume depending on load, speed and temperature.

Instead of intake and exhaust valves, the engine merely has intake and exhaust ports the rotors uncover at the right position in their circuits, almost like a two-cycle engine. Since the chamber is growing larger while the intake port is uncovered, it develops a partial vacuum that draws the air-fuel charge in just like a piston engine. There is one unusual feature when the rotor passes the exhaust port: The pressure drop happens *right now* so the acoustic pulse from the engine is very sharp. Even people who like loud exhaust notes find this sudden sound pulse too much and fit their rotaries with mufflers.



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One feature of the engine's design is how the rotors themselves are cooled: by oil only. This requires a separate oil cooler, of course, because a significant portion of the engine's waste heat goes into the rotors. An oil thermostat keeps the rotors from becoming too cool for their job under some circumstances, because a low temperature would cause poor fuel economy, fuel condensation and carbon deposits (of which more later). It also requires more attention to the quality of oil and the frequency of oil changes than some car owners are disposed to practice. And since the oil cooler is so critical to the operation of the engine, make sure it never gets clogged with leaves or road debris.

## Compression Testing

The most conclusive test there is for the mechanical condition of a piston engine is a wet and dry compression test. Doubtless you run such tests regularly for customers' cars in your shop. The rotary engine requires the same kind of compression conditions as the piston engine, but measuring it is a more complicated task. It's simplest with a special compression tester available from Mazda, but that tester is not so inexpensive you'd be tempted to buy one to check one engine. Other than shipping the car off to the dealer to run that test, it is possible to use your regular compression tester for an approximation.



With the engine opened up for overhaul, you can see the epitrochoidal chamber with the convex triangular rotor. Around the outside are passages for the engine through-bolts and the water jacket. Inside the rotor you can see the eccentric shaft bearing and the mesh between the rotor teeth and the stationary teeth. The circular seal around the center of the rotor keeps oil inside to cool the rotor surfaces.



Overheating a rotary engine can be as catastrophic as overheating any other. Here the housing is warped from the temperature.



It doesn't take much of a crack to lose compression. This broken apex seal meant two lobes of the rotor had no compression.

First, remove the Shrader valve from the tip of the tester, so the tester will not retain the pressure from one compression stroke to the next. Because a single port tests three lobes of the rotor, you're not going to find things out in the detail you'd expect on a piston engine. It doesn't matter which plug you remove to do the test, but obviously the other one must remain in. Watch the needle on the gauge very carefully: It should oscillate to about 75 or 80 psi. for each passing lobe. It won't go higher because you're effectively seeing only the first compression stroke of each lobe — this is a compression test on a piston engine in which you only get one puff per cylinder. Such a test is not useless, however; there is much to be learned from that first puff!

If you have more than one compression tester, use the one with the shortest or no connecting hose to eliminate the extra internal volume. Don't use a high quality oil-dampened gauge because you'll never see any needle pulses.

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*If there is damage to the apex seal, there is likely to be damage to the surface it rides on as well.*

If there is damage to an apex seal, this will dump the compression on both lobes on either side of it, so you'll see only one pulse per cycle, between the remaining two good seals. There's nothing to be gained from a wet compression test, since there are no valves to compare to the piston rings for sealing. In this you're testing side seals and apex seals only. If you find zero compression on one of the rotor housings, check the lobes with an inspection mirror or a borescope. It is possible someone put spark plugs with too long a reach into the engine. Just as spark plugs with too long a reach can punch holes in pistons in a conventional engine, spark plugs with too long a reach can snap off apex seals on a rotary. Similar damage results if someone drops a nut or carburetor check-valve ball down the intake. If you turn the engine slowly while watching through the spark plug holes with an inspection mirror, you can see the damage. If you find one with a missing or seriously damaged air filter, that could have the same consequences. Then that one's off to the rebuilder.

*Foreign objects, bolts and lock washers, won't blow harmlessly through the Mazda rotary any more than they will through a piston engine. Notice the carbon buildup on the one rotor, too.*



*The system injects a small amount of oil to lubricate the apex seals. When that system breaks down, as here, you'll see damage to the housing caused by the unlubricated apex seal.*



*No oil or little oil means no or little lubrication. And that in turn means an end to the bearings, stationary gear teeth and other internal components. Rotaries are very sensitive to oil quality and temperature.*



*'If some's good, more's better!' Not when you're talking about silicone sealer in an oil passage. There was enough of it here to function as a fixed orifice, restricting the flow of oil from the pump to the engine.*

Very often you will find a rotary engine with poor compression not because of mechanical damage or wear at all but simply because of carbon deposits on the seals and in the chambers. These carbon deposits, of course, make the seals lift from the chamber wall and spill their compression either forward into the previous chamber or backward into the following one. Most often this results from one or both of two causes: using the wrong gas — check with the owner's manual for the grade and with other rotary motorists in the area for information about specific brands and sources — and making short trips at low loads. The engine is designed for running fairly hard, and if someone uses it once a day to drive two or three miles to work and back home, that engine will soon grow carbon deposits that will make it refuse to start. Such carbon deposits can sometimes be removed with carbon and other engine cleaners.

That diagnosis reminded me of a flap about twenty-five years ago. Some high-performance sports cars — I think it was Porsche — were fouling spark plugs when driving slowly in traffic. The incautious and not-yet-market-savvy TSB said something like: 'Advise customer car was not designed for driving slowly in traffic.' This may apply to the RX-7 as well, even if they don't put it that way. ■

—By Joe Woods

*Photos courtesy of Atkins Rotary. Thanks again to David Atkins of Atkins Rotary Engines. If you need more information than is here, contact him by circling number 121 on the Reader Service card.*