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FUTURE TECH

An engine miracle?

A family-owned American engineering business claims to have perfected a new engine concept that could be in production by 2014. By Jesse Crosse

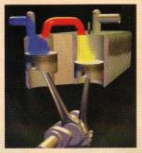
FOR ALMOST AS long as the car has been around the engines that drive it have remained fundamentally unchanged. The two-stroke has appeared a few times, but mostly it's been the Otto Cycle engine, better known as the four-stroke, that's dominated the scene. But now an American family business thinks it has a better idea.

The Scuderi Split-Cycle Engine – being developed in naturally aspirated, turbocharged and air-hybrid versions – is based on an idea that's been around since the 1890s, but so far no-one has managed to make it work. Now the Scuderi family reckons it's made a breakthrough and expects to better the fuel consumption and CO_2 emissions of conventional four-stroke engines by 50% using its air-hybrid system.

In a conventional four-stroke each cylinder follows the sequence of induction, compression, power and exhaust. Four strokes, two revolutions of the crankshaft with one combustion event and one power stroke. Some of the energy from the burning fuel produces power, but lots is wasted as heat either in the exhaust or via the radiator. The split-cycle engine replaces each cylinder with two. One, the 'compression cylinder', does the job of induction and compression, while the other, the 'power cylinder', takes care of power and exhaust.

The power cylinder fires on every rotation of the crankshaft like a two-stroke and twice as often as a conventional four-stroke cylinder. For this reason, the split-cycle engine has the same number of cylinders and roughly the same number of moving parts as a conventional four-stroke and suffers similar frictional losses, not more. So a conventional four-cylinder engine whose cylinders each fire every two rotations of the crankshaft, is replaced by a split-cycle engine whose two power cylinders fire every single rotation of the crankshaft.

Both compression and power cylinder have valves like a normal engine but there's a connecting passage linking the two. The cool cylinder simply acts like a pump, drawing in air and compressing it. The compressed air is released into the connecting passage by its 'exhaust' valves then, at exactly the right moment, inlet valves open in the power cylinder allowing air to enter under extremely high pressure just as the piston reaches top dead centre. As that happens, fuel is introduced behind the inlet valves by a high-pressure injector to cope with the high pressure in the cylinder. The huge pressure at which the air enters the cylinder produces a considerable amount of turbulence to mix fuel and air thoroughly.



Compression cylinder delivers high-pressure air to power cylinder

The time at which things happen is critical. All the compression is done by the compression cylinder, the compressed air entering the power cylinder just as the piston starts its downward stroke so compression doesn't happen twice. This is where the split-cycle engine differs from a conventional four-stroke in another respect. The fuel is ignited 10-14 degrees *after* the piston has passed top dead centre instead of 10 degrees before, lowering peak temperatures and subsequent emissions of NOx by around 80%.

Like a diesel and some direct-injection petrol engines, the engine runs 'unthrottled', reducing 'pumping losses.' Instead, air entering the power cylinders is controlled by pneumatically controlled, variable-lift inlet valves.

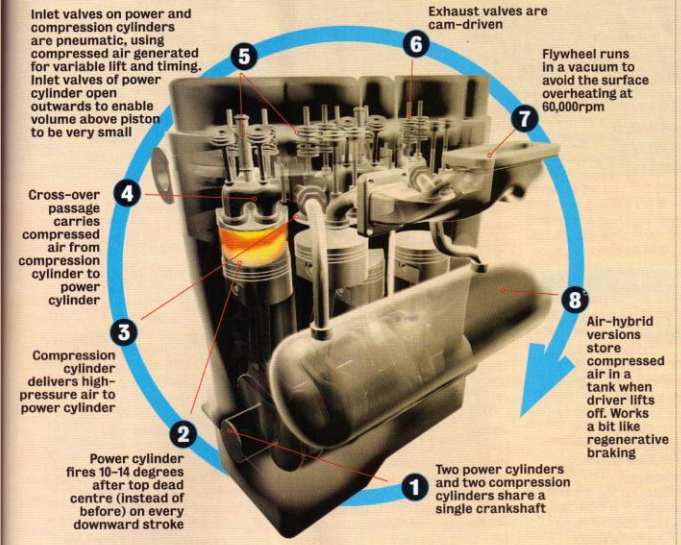
Naturally aspirated versions of the engine are claimed to be 10-15% more efficient at part load with turbocharged versions showing an improvement of between 15 and 20%. In air-hybrid mode, where energy is stored as compressed air when the driver lifts off the throttle, efficiency levels are even higher.

The engine's driveability characteristics differ from a conventional four-stroke. It revs lower, the current naturally aspirated prototype peaking at just 4500rpm, but Scuderi has plans for a faster engine revving to 6000rpm. The torque characteristics are similar to that of a diesel with plenty of low-down punch and a flat torque curve. Max torque of the turbo version is equivalent to that of a turbodiesel. Yet the specific power of the naturally aspirated version is a healthy 90bhp/litre while the turbo hits 135bhp/litre.

Radically new engine concepts usually sink without trace, but Scuderi says it has serious interest from '14 of the top 20 manufacturers' and expects the first licensing deal to be signed this year. And its ambitions don't end there, either. It plans a diesel version and aims to start testing that in 2012. One huge thing in the new engine's favour is that the components used to make it are those of a conventional four-stroke. Scuderi believes that a manufacturer could have the engine in production in as little as three years.

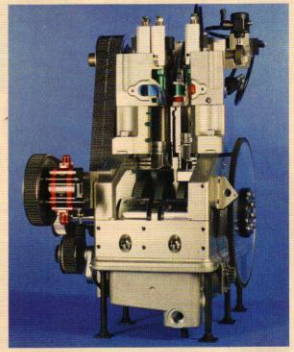
HOW IT WORKS

SCUDERI'S SPLIT-CYCLE ENGINE



CLEVER STUFF

WHY IS THIS ENGINE SO EFFICIENT?



THE MAKER SAYS its split-cycle engine has greater thermal efficiency so more of the energy it produces is converted to power rather than heat. Early attempts were inefficient and Scuderi claims the breakthrough came in successfully igniting the fuel after top dead centre, when the piston has already begun its power stroke, rather than before it, when the piston is completing its compression stroke. Compression pressure in the cylinders is very high and this also aids efficiency. The high pressure is made possible because two of the four valves in both the compression cylinder and the power cylinder open outwards rather than inwards, allowing the space above the piston to be reduced to less than 1mm. So pressure in the cross-over passage between the two cylinders is around 50 bar – similar to that in the combustion chamber of a conventional engine during combustion.

The air-hybrid system also adds efficiency. It comprises a surprisingly small, steel air tank and a couple of extra valves. When the driver lifts off the accelerator, valves divert air from the compression cylinders into the receiver. Once back on the accelerator, valves let air in the compression cylinders escape so the engine no longer has to work to drive them. The power cylinders draw the air they need from the tank instead. This method of recovering energy is more efficient than the process of regenerative braking in an electric hybrid system. Battery systems charge slowly and release stored energy quickly, but the air-hybrid system is the opposite. Scuderi says a 1.0-litre engine can charge a 20-litre tank in 15 seconds but can power the engine for a longer period.

There are difficulties to overcome. One of the problems designers of all piston engines have wrestled with over the years is that of timing. If an engine has a stroke of 90mm its pistons will travel at an average speed of 18m/s at 6000rpm. There's little time to open valves, get air and fuel in, close the valves and ignite it. Because the Scuderi cycle fires when the power stroke has already started, that time is reduced even further so valves have to lift and land very quickly. Cooling is another challenge. A conventional four-stroke is cooled by the induction stroke drawing cooler air into the cylinder. The Scuderi cycle power cylinder has no induction stroke and it fires twice as often. Engineers have overcome the problem by passing coolant around the power cylinders first and the compression cylinder second.