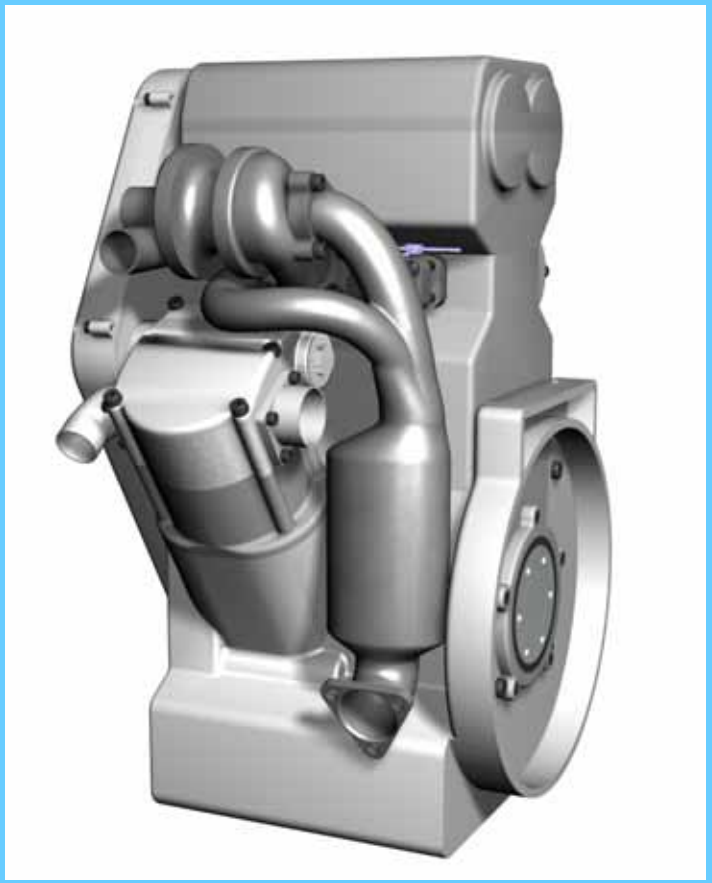
The Z engine, an economical alternative to a hybrid system



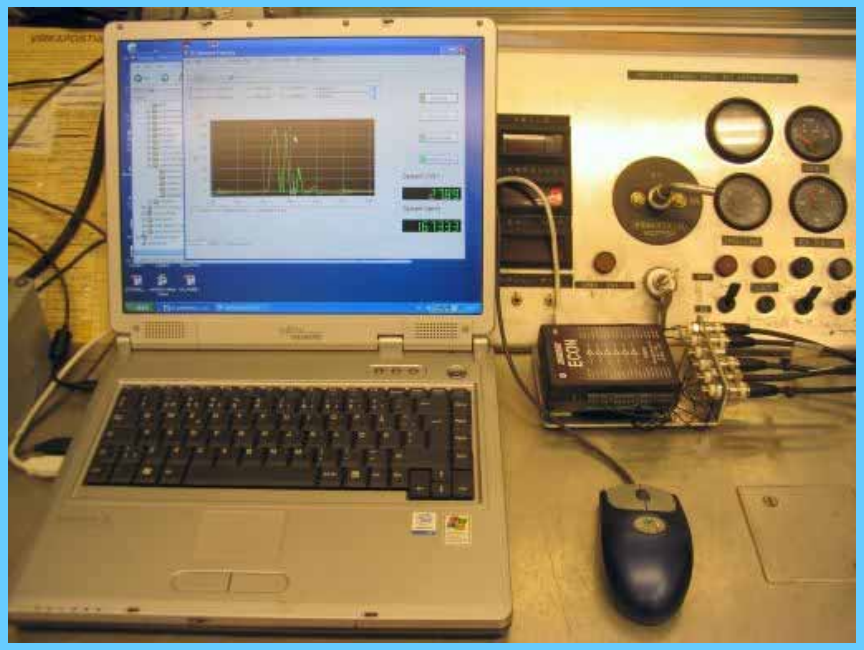
Z engine project

In 1999, Aumet Oy began to research a 4/2-stroke car diesel engine called the Z engine, in co-operation with the Internal Combustion Engine Laboratory at the Helsinki University of Technology (HUT) and the Energy Technology Department at the Lappeenranta University of Technology (LUT). So far, three master's theses, two SAE-papers and one Fisita-paper have been completed on the subject. Modern simulation tools, such as Star CD, GT-Power and Diesel RK have been used in those theses. Aumet's research project is part of the Finnish Engine Technology Programme, ProMotor, and it is supported by the National Technology Agency Finland, TEKES. A prototype engine made its first start in December 2003 and testing of the engine started spring 2004. Since then the engine has been in a test bench at VTT (Technical Research Centre of Finland).

The Z engine has got three international patents until now. Several international patents are pending.

The prototype engine

The prototype engine in the test bench



The data acquisition

The Z process

The main principle of the Z engine is to make a part of the compression outside of the hot work cylinders with an external compressor. The compressed air is lead into the work cylinder through the poppet valves when the piston approaches the top dead centre.

The compression is made by a two-stage compressor set. The first-stage is a pulse turbo charger and the second-stage is a piston compressor that is integrated into the engine.

There is an adjustable intercooler after each compressor stage for the control of the temperature. The pressure level of the external compression varies from 7 to 15 bar, depending on the speed and load of the engine.

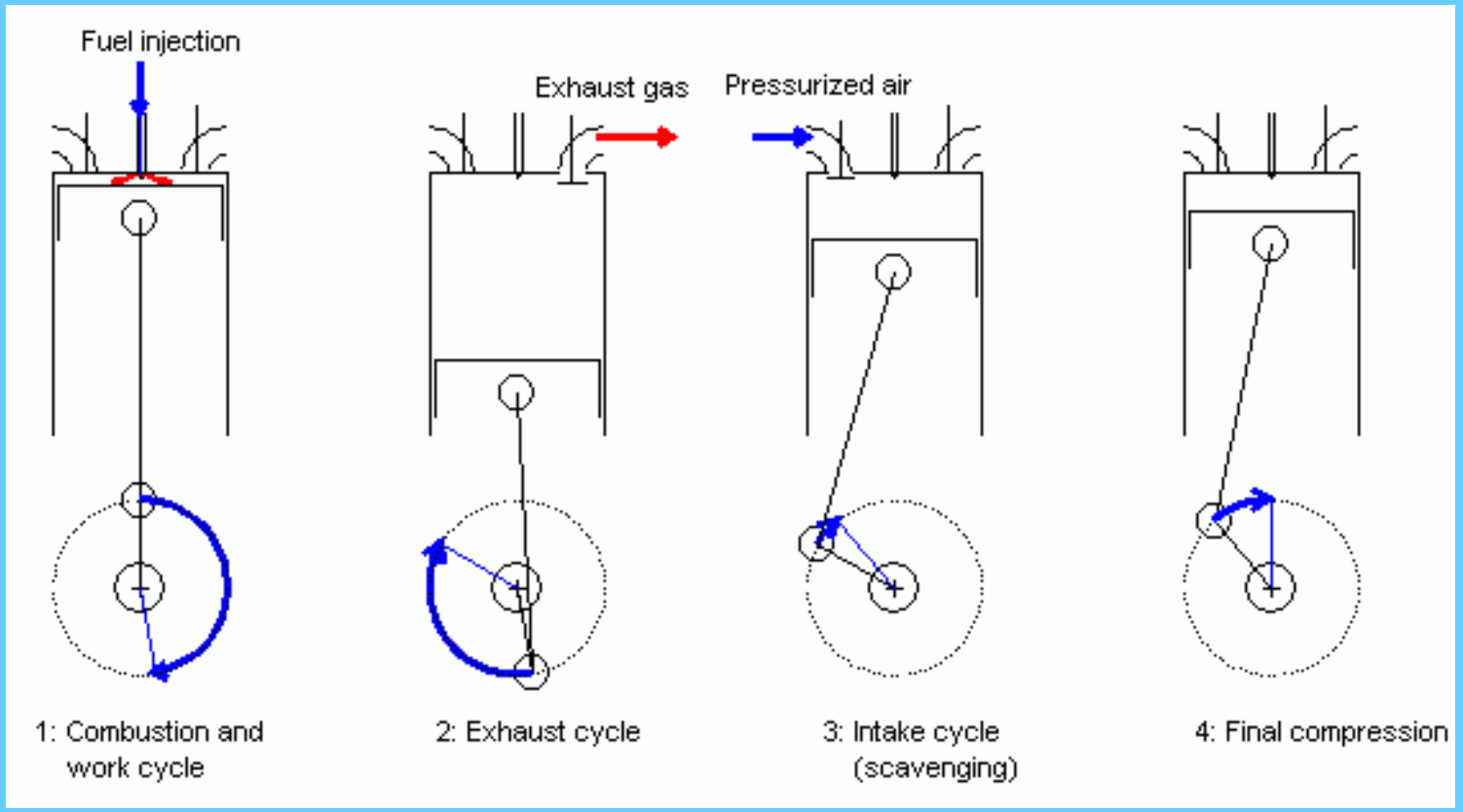
Thanks to the high intake pressure level, the intake cycle is very short, typically 20° of the crankshaft. After the intake/scavenging, the air is further compressed in the work cylinder.

The work cycle is like in a 4-stroke engine. The exhaust valves are opened about 60 ° before the bottom dead centre. Then the rising piston pushes the exhaust gases out of the cylinder until the exhaust valves are closed and the intake valves are opened, typically 60° – 40° BTDC.

The amount of the internal EGR can be controlled by adjusting the overlap of the valves. The hot EGR acts as an internal heat exchanger in the Z-process.

The gas exchange of the Z engine

The Z engine is a 4/2- stroke engine producing work at every stroke of each piston. The gas exchange is controlled by means of poppet valves. The work cycle of the Z engine is identical to that of a 4-stroke engine.

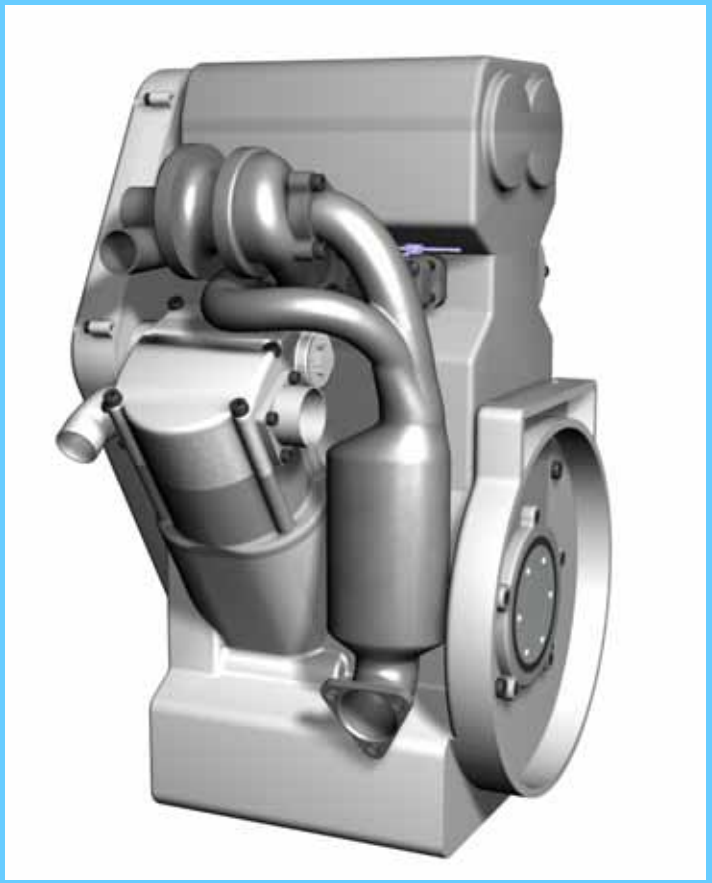


The Z combustion

The Z combustion chamber is a combination of the swirl combustion chamber and the “Perkins squish-lip” combustion chamber.
The Z combustion works with an air/fuel ration of 1,0 independently of the load of the engine. Thus a 3-way catalyst can be used and the NOx output is very low.
The swirl ration is 30 – 50 in the Z combustion chamber, like in the swirl chamber engines.
The high speed squish flow is generated by having a small opening diameter of the combustion chamber in the middle of the piston like in the “Perkins squish-lip” combustion chamber and by having a small piston – cylinder head clearance, about 0,2 – 0,4 mm. This is possible as the gas forces are always “downwards” in the Z engine and also the bearing clearances.
As the combustion chamber of the Z engine is very small and compact, it is possible to reach all the available air (90 – 95 % of the total intake amount) within the very short injection time. There is a good contact between the high speed, high turbulence air and the conical fuel sprays, making a rapid mixing possible. The duration of the injection is about 10 ° of crank angle, starting 10 ° BTDC. The nozzles, 1-3 pcs/cylinder are outwards opening conical nozzles (like CAV Microjector). There is enough flow area for a rapid injection even the gab between the conical needle and the injector frame is only 0,05 mm. The flow area is 5 – 10 times bigger than in an equal direct injection system. The injection pressure can be only 200 – 500 bar and this gives 2 – 3 % advantage in the fuel consumption, when compared with systems working at 2000 bar.

The Z engine, outlook

A 2-cylinder Z engine is equal to a 4-cylinder 4-stroke engine in its power output and balancing.



The Z engine, turbo and compressor

The Z engine has a pulse turbo charger and a super charger (piston compressor)

The Z engine, balancing

As the camshafts of the Z engine rotates with same speed as the crank shaft, the mass moment of 1. order can be balanced with counterweights at the ends of the cam shafts. Thus the balancing of the Z engine is equal to a 4-cylinder, 4-stroke engine.

The advantages of the Z engine

- NOx and particulate free high turbulence combustion.
- air/fuel ration 1,0 independently of the load, 3-way catalyst possible
- high efficiency especially at part load (Atkinson cycle)
- good balancing, equal to a 4-cylinder, 4-stroke diesel engine
- small size, 40% smaller than an equal 4-cylinder, 4-stroke diesel engine
- low weight, 30% lower than an equal 4-cylinder, 4-stroke diesel engine
- low cost, 30% lower than an equal 4-cylinder, 4-stroke diesel engine
- quick warming
- good cold start behaviour (bypass of the intercooler after the compressor)
- short crankshaft, no torque vibrations
- normal components, no need to any changes in the supply chain

Comparison: the Z engine versus a hybrid system

- better overall efficiency, higher than 35% (hybrid system 25 – 28%)
- lower weight, (50% lower)
- smaller size, (50% smaller)
- lower cost, (50% lower)
- less complex to manufacture