Z-ENGINE

A BRIEF DESCRIPTION

Background

In the technical development of the internal combustion engine the protection of the environment has become the most important issue in the western countries. The emission norms of the diesel engines are tightening and are getting really hard to be fulfilled. For example a number of big US diesel engine manufacturers have to pay a penalty of $ 83,4 million for sales of engines noncompliant with EPA emission standards.

With today's technical solutions the CI engines are substantially better in efficiency than the SI engines. The unfavorable drawback of CI technology is the 'NO_X – PM - Fuel consumption' trade-off. Using normal techniques the simultaneous optimization of these three parameters is not possible. A rather complicated and expensive exhaust gas after-treatment for NO_X and PM emission is needed in near future in order to fulfill the requirements of stringent emission standards.

The power output of the SI engine is limited by the knock phenomena that again sets limits to the compression ratio. Car engines are run at partial loads most of the time in the operation. If, in some way or another, a reliable system to control the compression ratio would be available, then the SI engine might be more competitive on partial loads.

The innovation

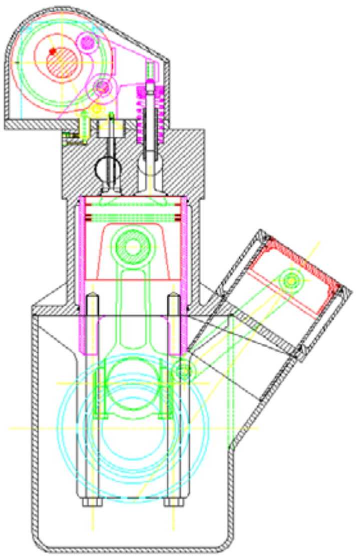
Aumet Oy has developed a new type of combustion process, the Z-Process, containing several new innovations. Compared to the generally used Otto- and Diesel-processes the Z-Process is based on completely new thermodynamic principles. The advantages of the Z-Process are low NO_X level, low particulate level, and high efficiency especially on partial loads. Those are achieved through the new injection and combustion technologies. No expensive catalytic converters are needed.

The first calculations of the Z-Engine were made already in the 70's (Janhunen). The next, more in-depth analyze of the Z-Engine combustion process and emissions was carried out in 2000 - 2001 in a Master's thesis at Lappeenranta University of Technology. Parallel to that, more complicated simulations of the Z-Process were carried out by the end of the year 2001 using the special software developed by Professor Larmi from Helsinki University of Technology. These simulations ensured that the Z-Engine could achieve approximately 20 to 25 percent lower fuel consumption than modern car diesel engines. On partial loads the difference can be as high as 50 percent, which is due to the 'Atkinson process' used in the Z-Engine.

Z-Process and Z-Engine

The Z-Process is a mixture of the two-stroke and the four-stroke processes. The natural advantage of the two-stroke principle is the increased power density. The engine includes a new innovative scavenging system with poppet valves like in the four-stroke engines. The Z-Engine produces work at every rotation of the crankshaft like the two-stroke engine. The scavenging through these poppet valves does not result in high emission levels like in traditional port scavenging. The piston removes the exhaust gases from the cylinder through the exit valves and the incoming gas enters through the intake valves and the gas exchange occurs at every crankshaft rotation. The gas exchange occurs during a very small crank angle close to the top dead center, where as in a two-stroke engine it occurs close to the bottom dead center. The gas exchange pressure is very high in the Z-Process, typically 15 – 25 bar, more than ten times higher than in a four-stroke engines.

Another innovative solution for reducing the emissions is the use of a separate compressor that pre-compresses the combustion air outside the combustion cylinder. This gives the engine designer a great advantage to influence the combustion - the compression pressure, compression temperature, and in-cylinder exhaust gas re-circulation can be chosen to optimum in every situation. This reduces NO_X emission to minimum and allows engine designer to use high geometrical compression ratio. The expansion stroke is more effective than in modern engines, which is the key element for good overall fuel efficiency. The geometrical compression ration of the Z-Engine is high - typically around 50, and the expansion ration is typically 20 – 30. (In four-stroke engines it varies from 7 to 10.) The new control of the pre-compressed gas temperature enables this high expansion ratio. In Z-Engine there is a secondary compression in the working cylinder after the gas exchange. During this period the gas pressure rises typically to 160 bar. The gas temperature is adjustable and can be kept at a reasonably low level. The high pressure of the incoming scavenging gas generates a rapid swirl. Like in swirl chamber engines the swirl number is typically from 10 to 40. In Z-Engine the combustion space (swirl chamber) is in the piston crown allowing the fuel injection with a conical single spray nozzle using a pressure of only 500 bar. The out coming fuel stream is "tube" shaped with a diameter of about 3 mm and the "wall thickness" of 0,03 mm only (like CAV Microjector).



Z-Engine, cross-sections for the in-line constructions.

The Z-Engine, both for gasoline and for diesel oil use, can be constructed as 'boxer' type or in-line engine with an integrated or separate piston compressor. It can also be fitted with a turbo- or supercharger like other modern engines of today. The number of working cylinders is only half of those in a four-stroke engine. The small size, low weight (high power density) with to reduced number of parts, as well as reduced cost on extra accessories leads also to lower production costs. For those reasons, the Z-process is the solutions for future engines in diverse applications. As the technical solution the Z-Engine can offer many advantages to car and engine manufacturers without re-structuring the supply chain or endangering the major production/assembly line investments. Implementing the Z-Process and Z-Engine technology in the final products is expected to be a rather smooth operation.

There are no technical limits for using Z-Engine design principles in designing engines using alternative fuels. The alternative future fuels in automobile use could be bio-diesel, oxygenated diesel fuel, synthetic diesel fuels, dimethyl ether, or alcohols. For marine and power plant large engine alternative fuels could be marine diesel oil, heavy fuel oil, orimulsion, opyrolysis oil, etc.

Applications

The possible uses for the new Z-Engine are almost all the products, where an internal combustion engine is or could be used as a power source. These include different kind of vehicles (passenger cars, trucks, busses, special vehicles), mobile working machines, stationary or semi-stationary power plants, and other industrial applications.

The share of diesel engines is expected to grow rapidly. The average share both in passenger cars and in commercial vehicles in Western Europe it is estimated to exceed 40 percent (France, Spain, Austria, Belgium, and Luxemburg more than 50 percent) of new passenger car registrations in 2002. The forecast in Europe in 2005 is close to 7,6 million new registrations (Ricardo, *'Diesel and Passenger Car & Light Commercial Vehicle Markets in Western Europe'*, 2002).

The smaller space requirement of the Z-Engine can offer new design options, too. The advantage of the new in-line Z-Engine is, that minor modifications in the front part will give more space and shape for improved crashworthiness in design (or more power from the same size engine). On the other hand, the new Z-Engine in its optimum is a 'boxer' that gives a lot more freedom for the vehicle design and chassis development. One of the possible solutions could be the under-body engine following the style introduced by A-series Daimler-Chrysler.

Also the avionic industry making small combustion engine powered airplanes is looking for new high efficiency diesel engines. A two-stroke solution offered by Z-Engine seems to be very attractive for them

Cost benefits

According to January 2002 price information a customer has to pay about 1.500 to 2.500 euros extra to get an equivalent diesel engine (from 75 to 110 kW) instead of a gasoline engine in his 20.000 to 25.000 euros car. The cost of the modern turbo-charged diesel engine (105 kW) is about 4.000 euros. If the same power is generated with an in-line Z-Engine, the cost reduction will be about 20 %. And still the main components used in the Z-Engine are the same as a traditional engine has, which means rather easy integration into the existing network of component manufacturers and other suppliers. The removal of the PM filter and catalytic converters generate another extra savings of 20 %. Reduced size of exhaust pipe, as well as other savings in chassis and other fittings can also generate similar savings in manufacturing costs. The total cost reduction can be as high as 12 – 15 %. In addition the customer gets a better fuel economy, and lower maintenance costs. With the European year 2005 diesel car sales figures this would mean average savings of about 23 billion euros.

In trucks and other heavy working machines the particulate filter and the catalytic converter meeting the new emission standards may cost more than 20.000 euros with the life span of the particulate filter of max. 400.000 km. The impact of this can be more than 100 percent in the machine price. Z-Engine application does not need this extra equipment to meet the new standards. According to a German study (Mollenhauer, 'Diesel Motoren', 2002) a heavy truck's life-cycle costs (840.000 km, 8 years) without salaries are: investment 21 percent, interest, insurance, taxes 17 percent, service 23 percent, fuel 35 percent, and tires 4 percent. Thus the Z-Engine solution can reduce the life-cycle costs by more than 15 percent.

For a 10.000 kW power plant the preliminary calculations indicate that life-cycle savings in fuel oil consumption when using a Z-Engine can be as high as the cost of the plant it self.

As the above examples indicate the Z-Engine can solve the huge emission problems in combustion process without excess costs and without increased fuel consumption.

R&D

The actual R&D started in 2000. The main concern of activities is in the technical development of the Z-Process and Z-Engine. The work will be done in close co-operation with the Internal Combustion Engine Laboratory at Helsinki University of Technology (HUT). In 2002 the focus is on the combustion process and the gas exchange, as well as on the testing of the 0-prototype engine. The combustion process and phenomena will be studied with the help of high-powered mathematical simulation tools. A test engine will be constructed to carry out more detailed measurements on the combustion process, power output and the emissions. The first results are expected to be available at the end of 2002.

The Aumet's *'5 x 20 percent car engine project'* is targeted to produce at least 20 percent higher efficiency, at least 20 percent lower manufacturing costs, at least 20 percent lower weight, at least 20 percent smaller size, and 20 percent or more reduction in the NO_X and particulate emission compared to what the normal high quality car engines of today can achieve. According to the results achieved there are good possibilities to reach the set targets.

TEKES, The Finnish Technology Agency, is co-funding the research through the national ProMotor-program, that the Z-Engine project is part of. Other national and private organizations like Runar Bäckstöm Foundation, Foundation for Finnish Inventions, and T&E Centre are also supporting Aumet in the work.

Promotion

The first presentation on the Z-Engine was given in Germany (*Automobiltechnische Konferenz 2001*, Wiesbaden, Germany 17-18.5.2001). Since that the Z-Engine together with the Z-process has been presented in a number of international conferences both in Germany as well as in Finland (*Engine Expo 2001*, Stuttgart, Germany June 2001, *ProMotor autumnseminar* in Hämeenlinna, Finland, September 2001, *Symposium Dieselmotorentechnik 2002*, Ostfildern (Stuttgart), Germany December 2001, *Engine Expo 2002,* Stuttgart, Germany May 2002, *FISITA 2002 World Automotive Congress*, Helsinki, Finland, June 2002, and *Virtual Product Creation 2002 Internationaler Kongress*, Berlin, Germany, July 2002).

Articles have been published in Finnish magazines (*Tekniikka & Talous*, June and November 2001, *Tekniikan Maailma*, October 2001 and April 2002, *Tuulilasi*, December 2001, and *Suomen Autolehti*, January 2002).

The next international promotion will be at the *Automobile and Engine Technology*, Aachen, Germany, in October 2002.

IPR

As the Z- Process and the Z-Engine are unique in the combustion engine field, they have been protected with patents. The first international patent application pre-study of the Z-Engine gave a very positive indication, i.e. all criteria on novelty, inventive steps and industrial applicability were met.

About the Company

Aumet Oy is a start-up company specialized in the development on the Z-Engine concept. The company was established in 1981 under the ownership of Timo Janhunen. The share capital of the company is 67.000,- euros. Janhunen outlined the first ideas of the innovation already in 1970's.. In 1999 Aumet took over the active role in the development and commercialization of the innovation work.

Aumet has its premises in Otaniemi (Espoo, Finland), at the Innopoli Technology Park, with two research engineers working closely with the simulation team of the Combustion Engine Laboratory at Helsinki University of Technology.

Timo Janhunen, the Managing Director (MSc from Helsinki University of Technology, 1974), has his special areas in engine construction, combustion engineering, thermodynamics, and chemistry, and 27 years experience as entrepreneur, in R&D, and international business management,

Professor Martti Larmi from the Internal Combustion Engine Laboratory at Helsinki University of Technology is the member of the Z-Engine R&D-project leading group, and is in charge of the process simulations.

Professor Matti Juhala from the Laboratory of Automotive Engineering at Helsinki University of Technology is assisting in the assessment of the Z-Engine applications.

For more information, visit our web-site www.aumet.fi.