August 26, 2019

FOUR STROKE ENGINE DESIGNED FOR FAULT-TOLERANT OPERATION AND HIGH FUEL EFFICIENCY

Verena Blunder
Bertrandt Ingenieurbüro GmbH

FOUR STROKE ENGINE DESIGNED FOR FAULT-TOLERANT OPERATION AND HIGH FUEL EFFICIENCY

Technical task:
Various ignition systems are used in the automotive industry, such as simultaneous dual ignition and dual sequential ignition. Simultaneous dual ignition promotes engine efficiency by initiating twin flame fronts, giving faster and more complete burning and thereby compression Crank angle increasing power. Although a dual ignition system is a method of achieving TDC optimum combustion and better fuel consumption, it remains rare in cars and motorcycles because of difficulties in siting the second plug within the cylinder head. Dual sequential ignition can deliver better fuel economy as simultaneous dual ignition whilst having the same redundancy (fault-tolerant design).
In addition, water injection systems, such as direct or indirect water injection, is used in many areas, for example to increase fault tolerance. However, direct water injection is not yet widely used.

Initial situation:
The problem that arises from today's state of the art is the lack of possible combinations of dual sequential ignition and water direct injection. In most versions, only an indirect water injection system is used. This results in a susceptibility to errors, which can lead to failures.

Solution:
The invention combines dual sequential ignition and water direct injection into the combustion chamber (in cylinder injection), and is failure-tolerant, that means, it is capable to operate even if one spark plug, one ignition coil, the fuel injector or the water injector of the cylinder has a failure.

The invented engine should have:

- At least five holes in the cylinder head
- At least two valves per cylinder: an intake valve and an exhaust valve
- At least two spark plugs per cylinder
- At least two ignition coils per cylinder, each spark plug having its own ignition coil pressure
- An ignition control unit and an ignition system capable of firing the two spark plugs of a cylinder with a time interval, after each other, sequentially.

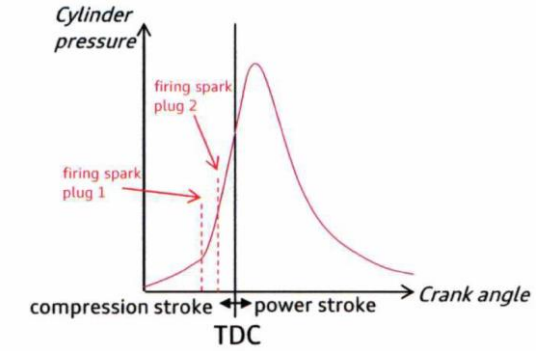

Figure 1

- At least one fuel injector per cylinder, injecting fuel either in the intake manifold (indirect injection) or in the combustion chamber (direct injection)
- At least one direct water injector capable of inject water or fuel in-cylinder. At normal operating conditions (no fuel injector fault) injected material should be true water, it should not be an emulsion, it should contain no fuel. In the case of fuel injector fault, direct water injector will be used to inject fuel in-cylinder. That means, direct water injector should be capable of inject fuel instead of water for safety reasons.
- Fuel injector fault detection system. If fuel injector fault is detected, operating liquid of direct water injector is changed to fuel, to be able to operate the cylinder. In this case, the cylinder operates without water injection.

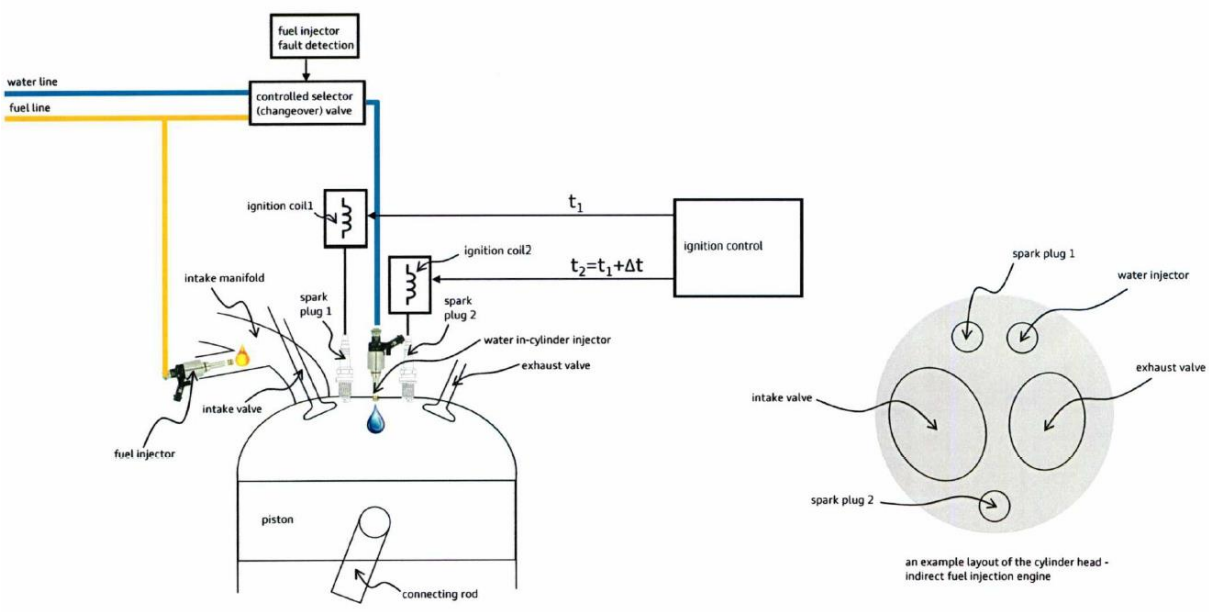

Figure 2: Indirect fuel injection engine

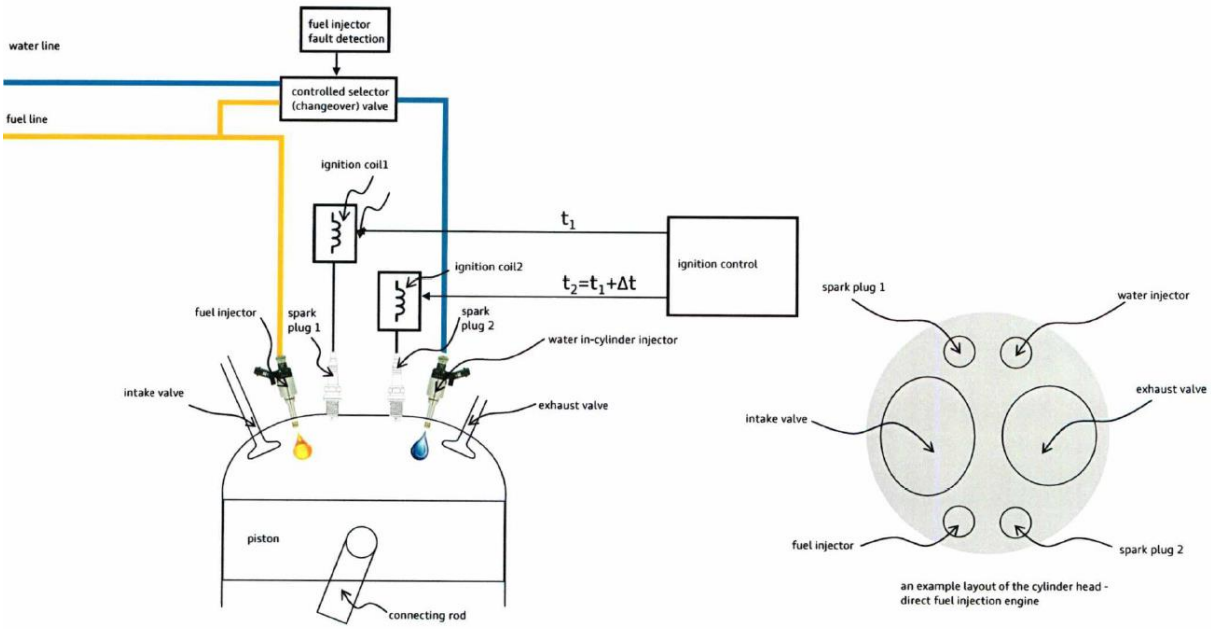

Figure 3: Direct fuel injection engine

Advantages:

Fault-tolerant operation

- If one spark plug fails: The other spark plug of the cylinder is capable to ignite the charge (fuel-air mixture), and therefore, the cylinder is capable to operate further, however, not as fuel-efficient as with dual sequential ignition.
- If one ignition coil fails: The other ignition coil and the related spark plug of the cylinder is capable to ignite the charge (fuel-air mixture), and therefore, the cylinder is capable to operate further, however, not as fuel-efficient as with dual sequential ignition.
- If the in-cylinder water injector fails: The cylinder operates further, however, not as fuel-efficient as with water direct injection.
- If the fuel injector fails: Fuel injector fault detection system detects the failure. If fuel injector fault is detected, operating liquid of direct water injector is changed to fuel. The cylinder operates further without water injection, however, not as fuel-efficient as with water direct injection.

High fuel efficiency

- Dual ignition: It is proven that a cylinder using two spark plugs can operate much more fuel efficient, as with a single spark plug.
- Fuel efficiency is further improved with introducing a possible time delay between the two sparks (dual sequence ignition.)
- Water injection: It is proven, that water injection can help to reduce fuel consumption of an engine with a proper control.
- Direct injection of the water makes it possible to inject water independently from the fuel, for example, at other crank angles, at independent times. Direct injection of the water makes it possible for the designer, to find a crank angle for the water injection to achieve high fuel efficiency depending on the load (torque) and speed (rpm) of the engine.

Optional:

- The engine can have variable valve timing to further improve fuel efficiency. If the intake valve is held open longer than normal, the engine could simulate an Atkinson cycle or Miller-cycle, to further improve fuel efficiency.
- The engine can have variable valve lifting to further improve fuel efficiency.
- The engine can be turbo charged to further improve fuel efficiency.
- Above techniques (variable valve timing, simulatedAtkinson or Miller-cycle operation, variable valve lifting, turbocharging) are compatible with the above invention.
- As an option, water injection system could run on water of the air-conditioning process (condensed water).

Possible application:

- In aircrafts as an aero engine
- In automotive applications