Introduction to
Fuel-Air Injection (FAI) Engine

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A FAI Engine is:

1. A clean two-stroke engine with fuel and air injections.
2. An air motor with internal combustor.
3. A single-stroke engine with virtual piston return.
4. A pulsating rocket engine with piston and crankshaft as the output.
5. A programmable combustion machine with digital controlled fuel and air injectors.

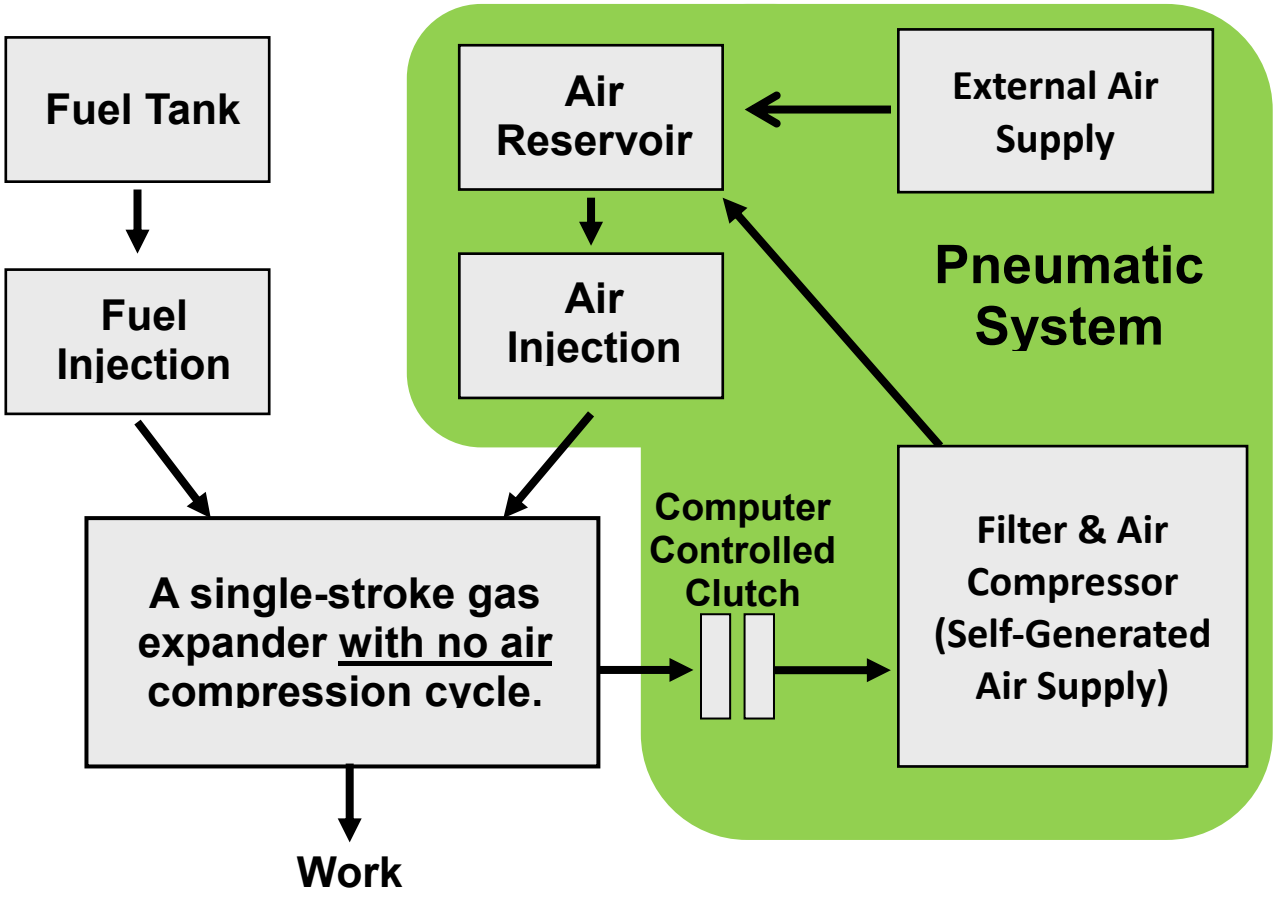


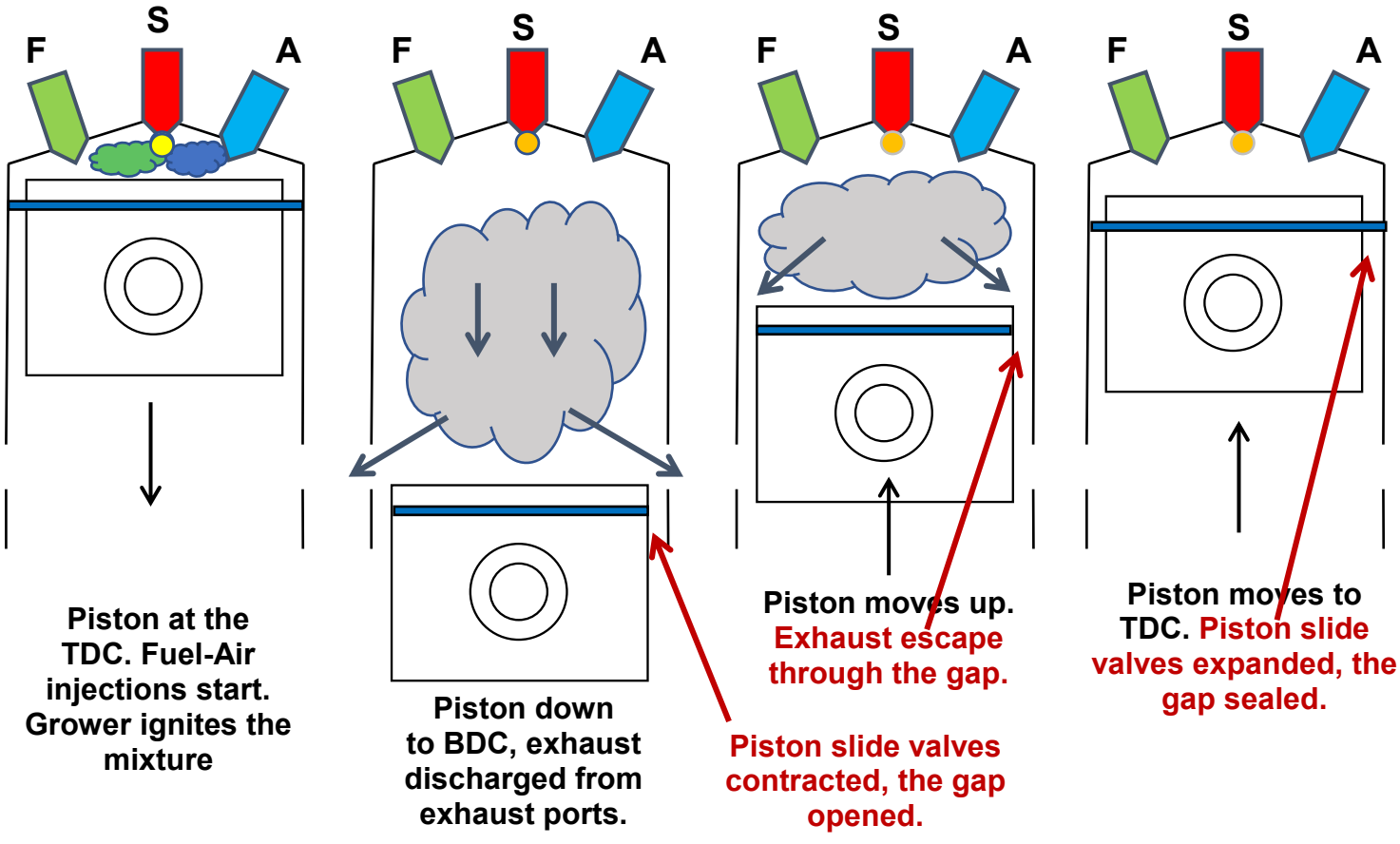
Fig. 1: FAI is a combination of an engine and an air motor.

How it works

Power stroke starts with fuel injection at about -10° nearby TDC (Fig. 2), fuel is evaporated in a pre-combustion chamber but not able to burn until air injection starts at TDC, the spark plug / flame holder ignites the fuel-air mixture and starts the combustion / gas expansion cycle.

The piston moves down to BDC, exhaust is discharged from the exhaust port and piston slide valves are pushed by lower cylinder registers to contract. The valve springs hold valves contract during piston move-up with remaining exhaust escape from the gap between cylinder wall and contracted valves. When piston moves to TDC, piston valves are pushed by upper cylinder registers to expand and holding expand by the pressure of injected air and expansion gas.

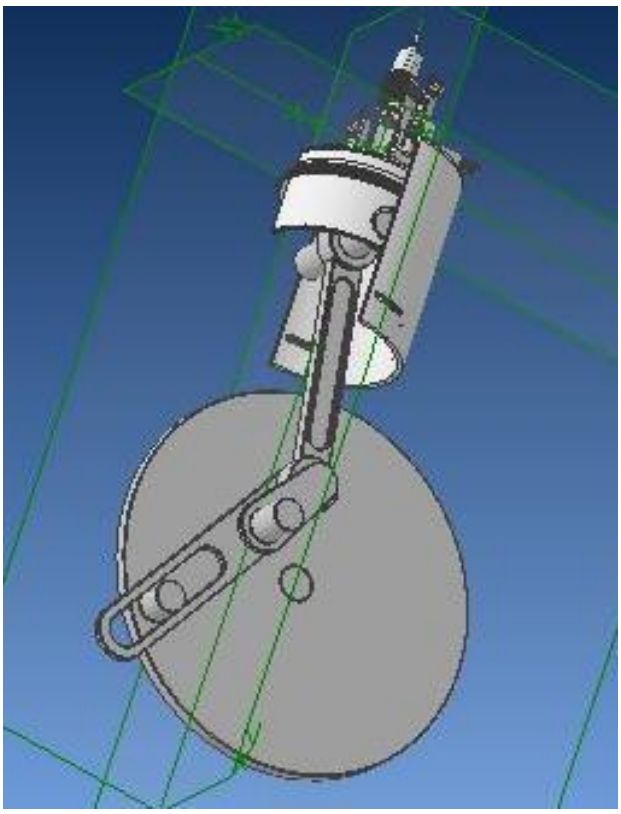
Fig. 2: FAI is actually a single-stroke engine. Piston valves are contracted during return stroke to reduce frictional losses.



Fuel-air injection timing and amount are programmable; combustion completeness and stoichiometric ratio are defined by software look up table and executed by digitally controlled injectors (ref. US patent 9121337, 9677468). Fuel can be liquid or gas phase such as alcohol, gasoline, diesel, eFuel or methane, propane, butane, etc.

FAI engine with virtual return stroke could take advantage of Whitworth Quick Return Mechanism [(1)] to increase the chemical reaction time and extend the duty cycle of the output.

Fig. 3: Optional Whitworth Quick Return Mechanism to extend chemical reaction time and smooth torque output.



Sample design with Quick Return Ratio (QRR) = 2:1

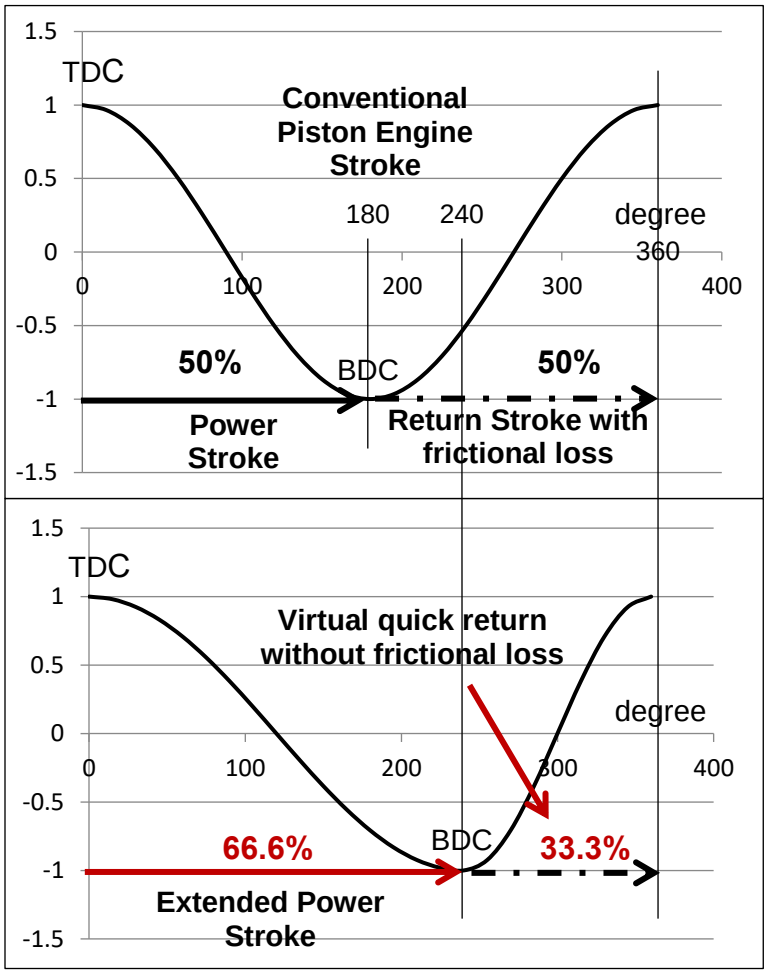
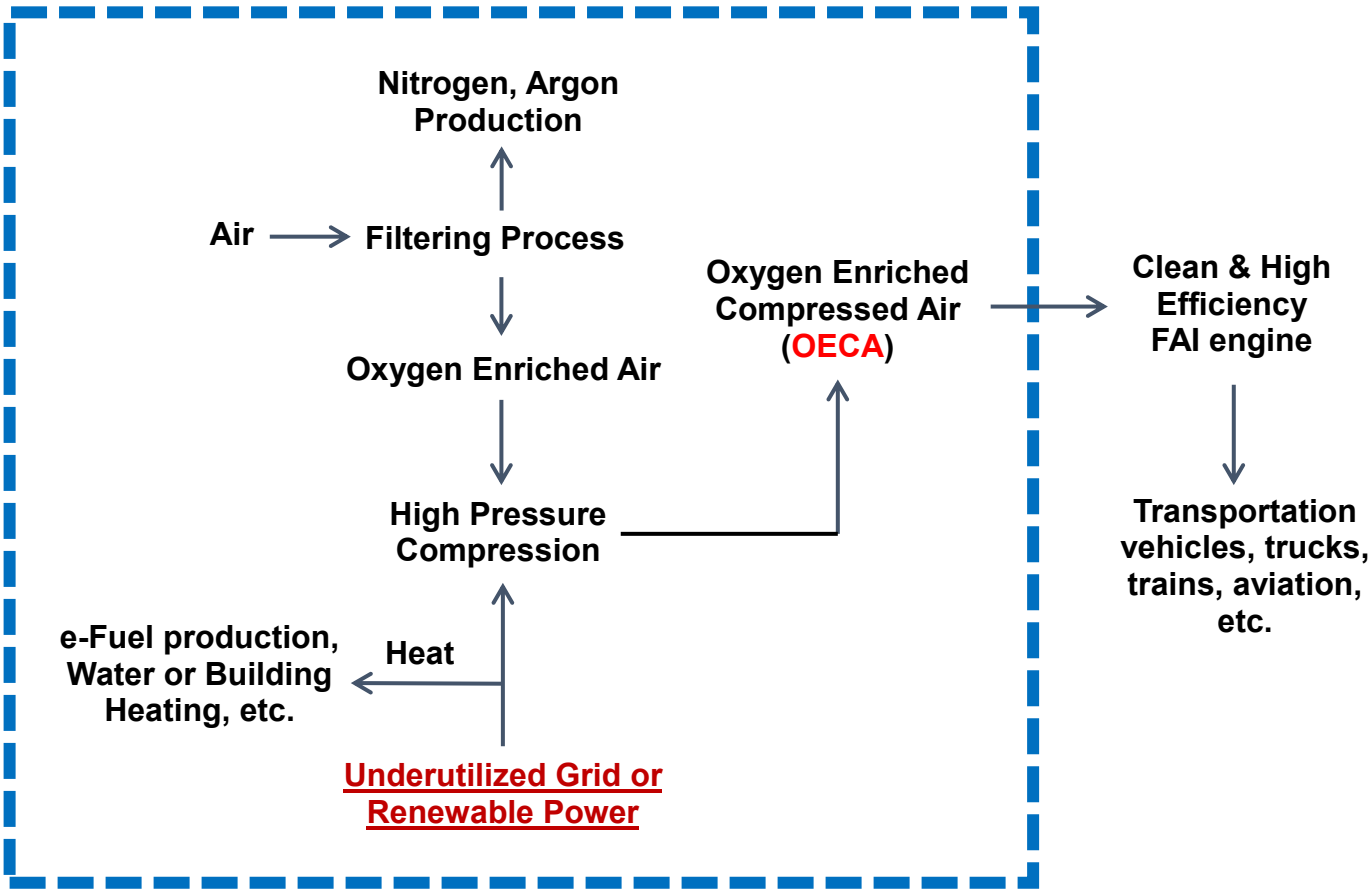


Fig. 3: Air supply with OECA for FAI



Advantages of FAI Engine

1. Dedicated gas expander with higher thermal efficiency and low noises due to programmable combustion and lower exhaust pressure.
2. Hybrid power to increase engine output range. Disconnect the computer-controlled clutch may offload the air compressor and system enters to hybrid power mode as long as the stored air last (Fig. 1).
3. Conventional poppet valves and valvetrains are eliminated and hence their associated heat and frictional losses (Fig. 2).
4. Contracted piston slide valves reduce 50% frictional losses during virtual return strokes (Fig. 2).
5. With Whitworth quick return mechanism [(1)], thermal efficiency and power duty cycle can be further increased (Fig. 3).

6. FAI engine may use Compressed Air Energy Storage [2] (CAES) for external air refill or with Oxygen Enriched CAES (OE-CAES) to achieve higher oxygen density and thermal efficiency as well as thorough combustion and NO_x reduction (Fig. 4).
7. Combustion is dominated by air injection, alternate fuels with various fuel type/property can be used with programmable fuel-air ratios.
8. Complete combustion is further ensured with extended air injection during peak power periods.
9. Uniflow to reduce turbulence losses.
10. Engine doesn't encounter air compression heat. Heat generated by air compression is shared by air compressor.
11. Engine starts with compressed air, no need for heavy duty batteries or starter.
12. Vehicle kinetic energy can be recovered with the air compressor.
13. Low system expansion cost - Increasing air tank capacity does not significantly increase weight or cost to the system.
14. FAI engine is operational under water.
15. FAI engine requires no special manufacturing process or rare material.

Comparison between FAI and Conventional Engines

FAI engine	Conventional engines
Pre-compressed oxygen enriched air injection	Real-time air intake and air compression
Dedicated gas expander and air compressor	Cylinder shared by gas expansion and air compression
Wide output range (Hybrid Mode)	Narrow output range
Reduced Frictional Losses	Severe Frictional Losses
Emission treated within the combustion chamber	Emission treated after combustion in exhaust system
Flexible Fuels	Fuel type/property dependent
Doubled power ratio	Poor power ratio

Applications

- Powerplant for long-haul transportation vehicles and trains.
- Range extender/battery charger for electric vehicles (EV).
- Powerplant for marine vessels, aviation or vertical takeoff.
- Farming, construction machines or hand power tools.
- Shaft drive for pump, compressor, generator, construction, farming machines or various heavy equipment.
- Power source for pneumatic field robots or exoskeleton.
- Air Independent Propulsion (AIP) for under water vehicles. OECA can be used as oxygen source for life support.

References:

(1): https://m.youtube.com/watch?v=zKa3ywes1lM&autoplay=1
(2): http://energystorage.org/compressed-air-energy-storage-caes