Air Injection for Internal Combustion Engines

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Oct. 7th, 2013
US patent #8434462
Agenda

● Efficiency and power loss due to 10% residual exhaust gas in cylinder
● Existing Solutions
● Proposed solution: Injected air flushing
● System hardware and cost
● Scavenging and Torque Curve
● Expected Improvements
● Combustion Physics
● Technology Demo And Future,A,B,C
● Characteristics of New Engine
● Summary
Internal Combustion Engine

Four-stroke cycle (or Otto cycle)
1. Intake
2. Compression
3. Power
4. Exhaust
Exhaust gas lower power and Efficiency

- Air pollution Requirements: EGR lower combustion temperature to avoid Nox formation: now we have three way cat.
- Motorcycles gain significant power and efficiency with muffler/cat removed
- Problem is greatest with partial load, gasoline engines and non-turbo engines
- We must reduce/eliminate exhaust back pressure, thus residual gas
Current countermeasures

- Dual exhaust system: Reduce back pressure by half, gain power/efficiency
  - Cost, weight, partial solution
  - Tuned header: performs only at one rpm.
  - Race car solution: Street illegal
  - Need new solution
Scavenging and torque curve

- Valves overlapping and exhaust tuning provide partial solution: Scavenging
- At certain rpm or band of rpm intake air flushes out waste gas when exhaust port has partial vacuum
- Low end or high end do not benefit
- Best solution, very narrow resonance
- Our solution flat from idle to redline
Direct air-injection (Air flushing)

- Inject high pressure air as piston reach TDC of cylinder during exhaust cycle
- Injector technology emulates fuel direct injector, fast actuator (ms) and billions cycle reliable. Controllable
- Air compressor, similar to fuel compressor, less demanding, less costly
- Need to sense piston at TDC
- Independent high pressure Turbo, 15 atm
- Simple and robust solution, low cost, proven reliability. Capacity tailor to engine size.
Invention

[Diagram of a device with labeled parts: 100, 110, 120, 125, 130, 140, 150, 160, 170, 175. Compressed gas is indicated at the top.]
Prior Art
Figure 4
Figure 5
Figure 6
Combustion Physics

- Chemical energy released go into heat
- H2O, CO2. Nox and hydrocarbon have vibration and rotation mode. They extinguish flames!!!!!!!. They rob energy that pushes piston (temperature and pressure)
- Cooking outdoor in a mist or light rain
- H2O and CO2 has twice the heat capacity
- Reference: John Heywood pp 405
Engine at idle

- Both air and proportionally fuel must be increased to overcome cooling effect of burned gas.
- Substantially more gas is needed to maintain rotation of the engine, as the burned gas destroys healthy combustion process.
- Two minutes of idling consumes gas that could move the vehicle one mile. Diesel burns only 40%
- Engine at idle, majority of “charge” is burned gas.
- With exhaust gas purging in place, we expect the fresh flushing air will provide more than enough Oxygen for combustion.
Design Considerations

- Power input must be a small fraction of power and efficiency gain.
- Compressor must be optimized for engine size and power proportional to rpm: Example: 2.0 liter engine at 3000 rpm, 6 cfm (average), 10 atm 1.5 hp power (compared to 10 hp gain).
- Fast and high throughput injector: storage tank, 5 ms duration air dump, 3/8 inch nozzle, check ball at tip, most critical component. Ultra high reliability.
- Intercooler optional, Turbo compressor possible, multi-stage compressor for higher pressure.
Technology demo and future

- Develop air injector or modify direct fuel injector
- Purchase low capacity 15 ATM air compressor
- Seeking funding for technology demo
- Modify single cylinder motorcycle engine head and install air injector
- Electronic control of air injection
- Establish low gas glow, low rpm idle operation
- Dyno mapping of engine performance, Torque curve
- Measure additional power for air injection,
- New engine development, injector automation, integration, reliability testing etc.
Emission Benefits

- For most stringent pollution control, air is already pumped into exhaust manifold to help CO and HC control with CAT.
- Direct air injection does it ahead of exhaust valves, in cylinders.
- Combustion temperature higher and thus air injection oxidizes CO and HC more completely without a Two way converter.
- Still need just one NOx converter.
- Cleaner emission than current gas engine.
New Engine Benefits

- At low (<2000) rpm it behaves exactly like Diesel, maximum torque, excellent gas economy, drives like Tesla.
- At medium to high rpm, it behaves like normal engine, high power at high rpm, still maximum torque.
- This engine has best of both engines and none of their disadvantages. Best case efficiency 40% better.
- Added benefit, additional oxygen injection for passing power if needed (ECU also provide fuel). Thus, torque/power boost mode.
- high performance AND high efficiency engine with very low emission, just Nox converter needed.
Chen Engine B

- Optimized flexible air injector requires development. Long adoption time and huge investment, billions.
- Chen Engine B is just modification of existing engine. Cam and exhaust valves/manifold.
- Take one of the exhaust valves to use as injector port. Modify cam to have short opening. Pressurized air remains the same.
- Performance will not be as good as A, but development time and cost several orders less.
Chen Engine C

- Simplest Air Injection engine
- Cam remains the same. Air is injected into cylinder during entire exhaust cycle
- One exhaust valve is used as injector port, same as B
- More air is needed for purging, thus more power needed for compressor, unless turbo pump is used.
- Efficiency is lowest, as more power needed for compressor
Summary

- Inject air to flush exhaust gas out, removing flame degrading H2O, CO2, thus improving efficiency.
- Low cost, low power, available technology, if necessary develop energy free high pressure turbo or others.
- New engine combines best of diesel and gas engines.
- Most environmentally friendly engine, better than Diesel or Otto engine, only pollutant is Nox.
- Model B and C can be quickly implemented.
- For B/C no change in engine control software/electronics.
- Next generation ICE, significant saving of energy resources and environment. Total impact of saving: over trillions.