Low Cost Air Hybrid Engine Concept

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Outline

- Brunel Air Hybrid engine concept
- Compressor mode VVT options
- Expander mode VVT options
- Systematic Study Plan
- Preliminary simulation results
- Future work
- Opportunity

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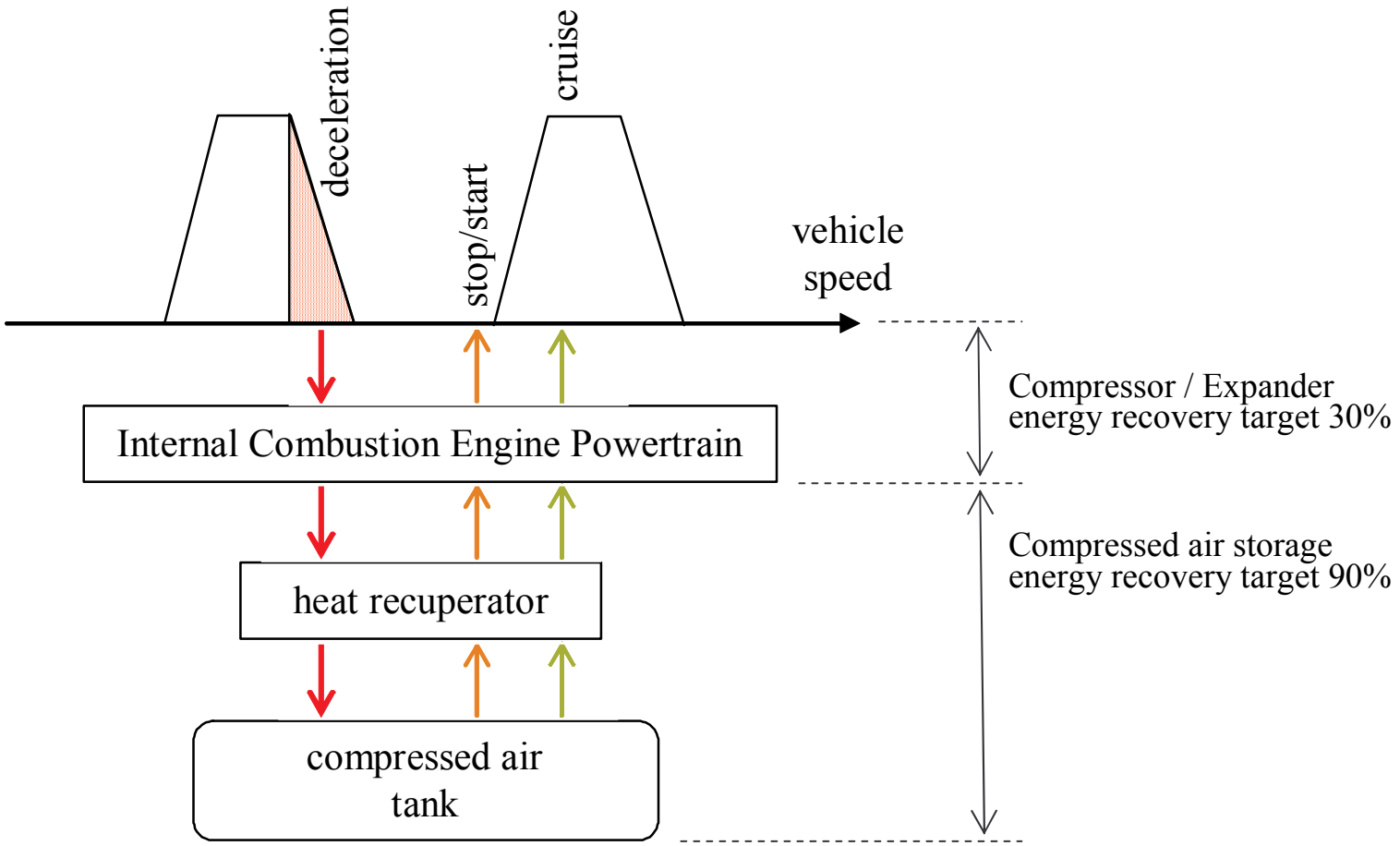
Brunel Air Hybrid Engine Concept



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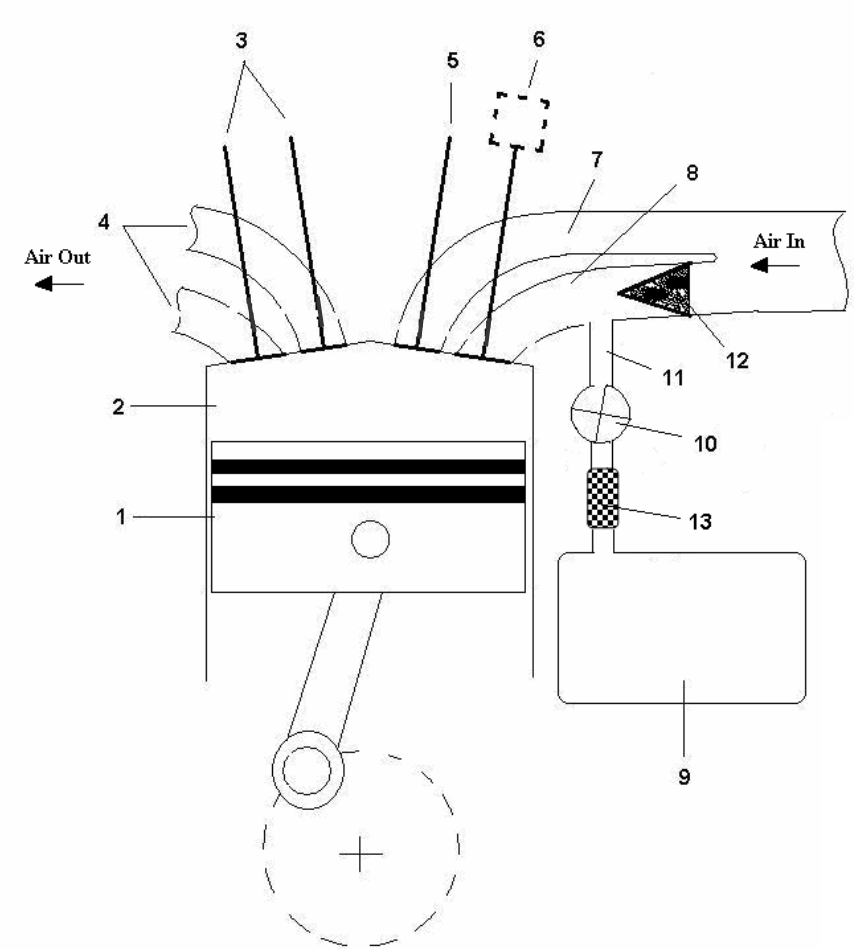
Brunel Air Hybrid Engine Concept



- Low cost modification to engine
- Non-return valve (12) at intake port entrance
- Energy Control Valve ECV (10) to air tank
- Heat recuperator (13)
- Compressed air tank (9) (< 20 bar)
- Retains 4-stroke engine operation
- Uses existing valves in combustion chamber
- Uses proven VVT technology
- VVT (6) options could be:
  - Cam Profile Switching CPS
  - Hydraulic Valve Stop HVS
  - Valve De-Activation VDA
- Retains standard vehicle transmission
- Adds little extra cost or weight

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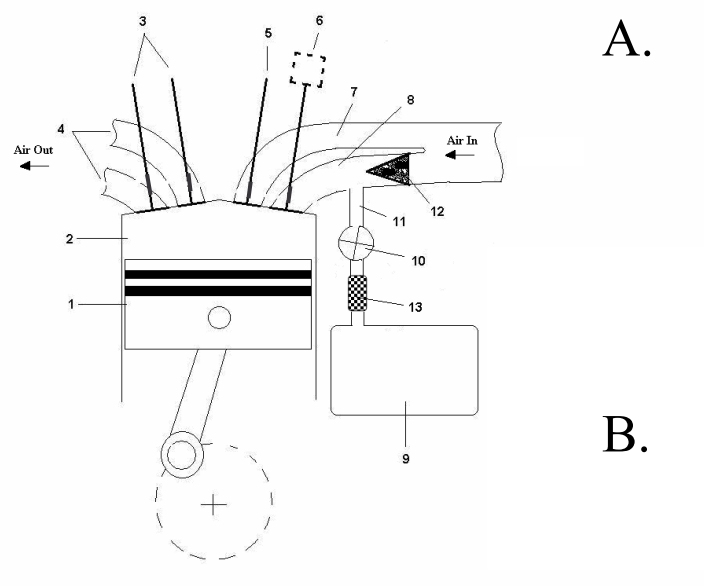
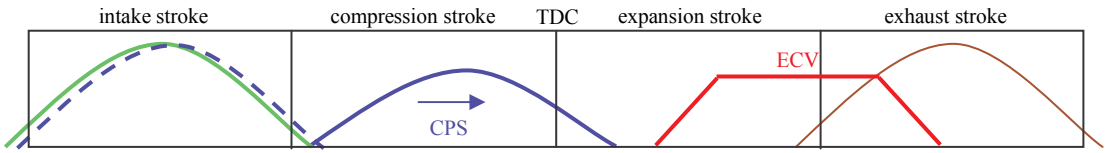
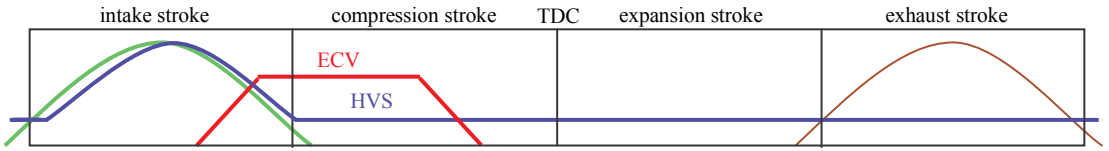
Compressor Mode – various VVT options



A. 4-stroke air compressor with CPS (intake valve) + solenoid controlled ECV for air transfer to tank



B. 4-stroke air compressor with HVS (intake valve) + automatic self-sealing ECV for air transfer to tank



Additional motoring torque during expansion stroke could reduces the braking torque required per unit compressed air produced i.e. 4-stroke compressor has high efficiency

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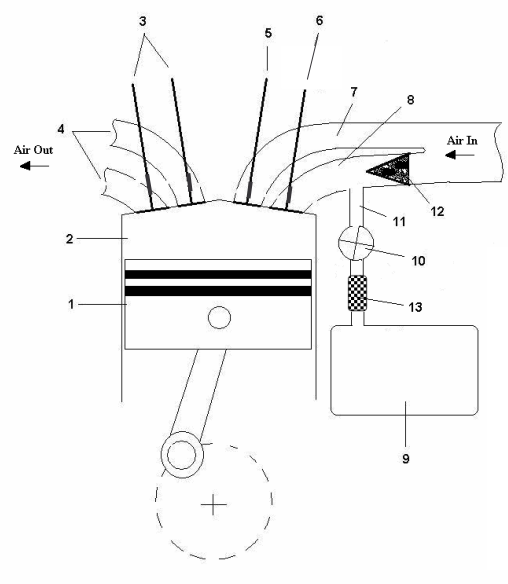
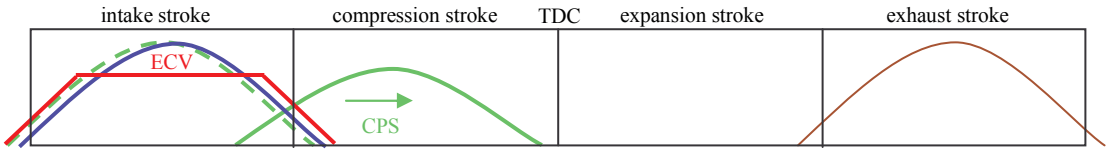
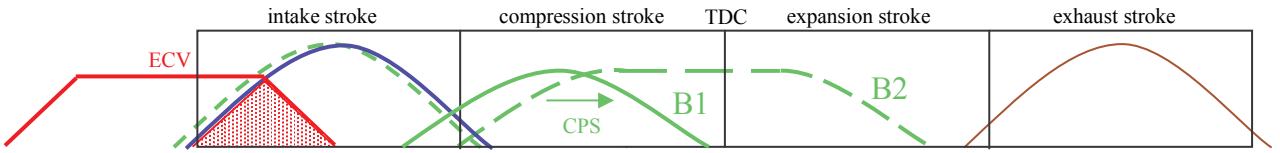
Expander Mode – various VVT options



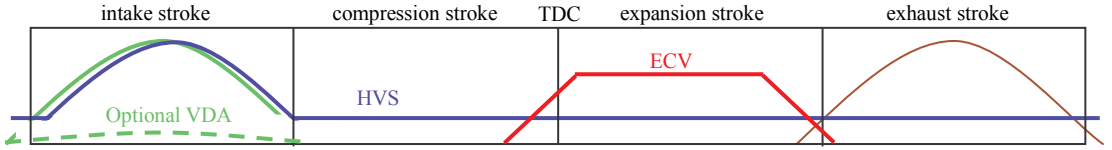
A. 4-stroke air motor with full intake-stroke ECV for maximum air admission during stop/starts + CPS



B. 4-stroke air motor with early closing intake-stroke ECV for metered air admission during cruises + CPS



C. 4-stroke air motor with full expansion-stroke ECV + HVS (intake valve)



Parasitic losses during the redundant compression and expansion strokes could reduce the nett motoring torque per unit compressed air used i.e. need to conserve expander efficiency

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Systematic Study Plan

- The various air hybrid VVT options will be modelled using Engine Simulation WAVE
- Optimisation for best compressor efficiency
  i.e. lowest specific $IMEP_b$ (per unit compressed air stored)
- Optimisation for best expander efficiency
  i.e. highest specific $IMEP_m$ (per unit compressed air used)
- Regenerative efficiency = specific $IMEP_m$ / specific $IMEP_b$

- Best VVT option will be used in Drive Cycle Vehicle Simulation
- Predict fuel saving from stop/starts using stored compressed air
- Predict fuel saving from cruising using stored compressed air
- Identify other benefits using stored compressed air

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Preliminary Simulation Results

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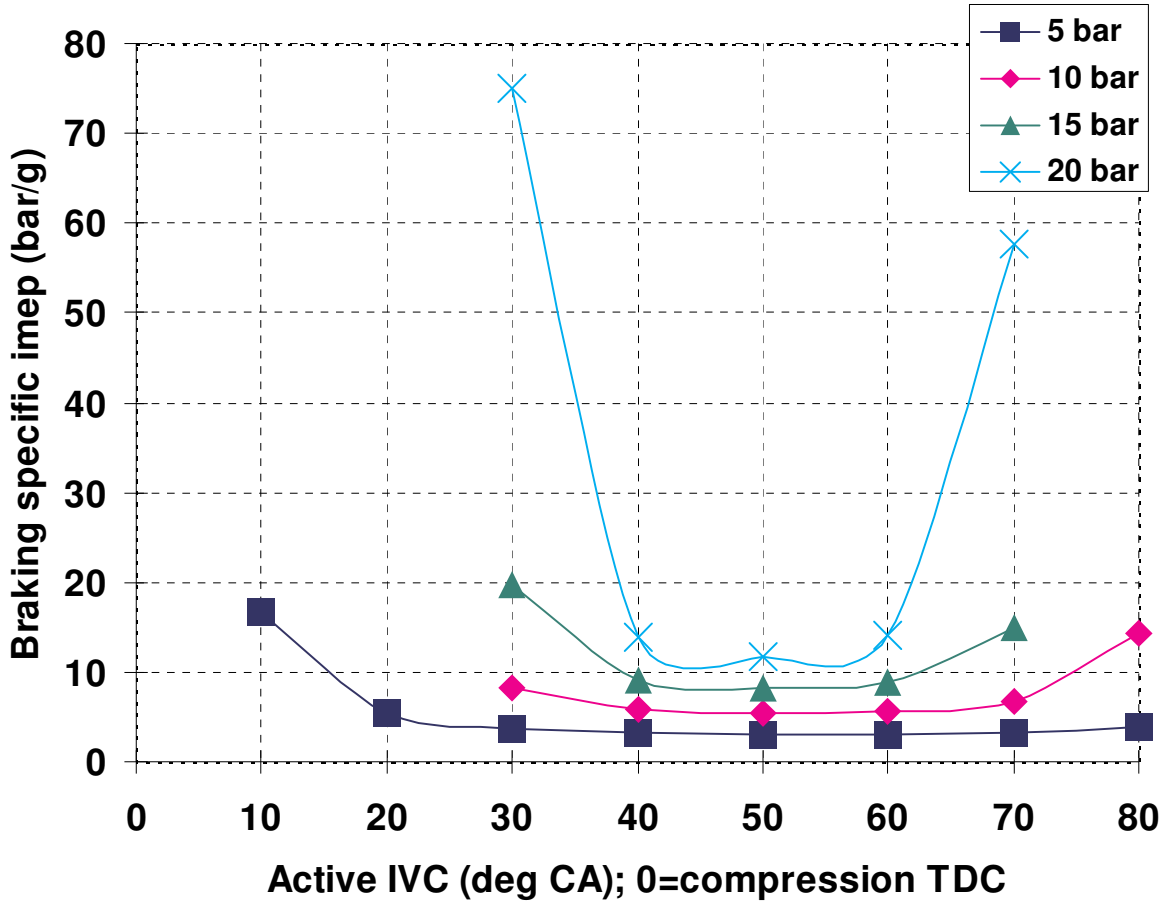
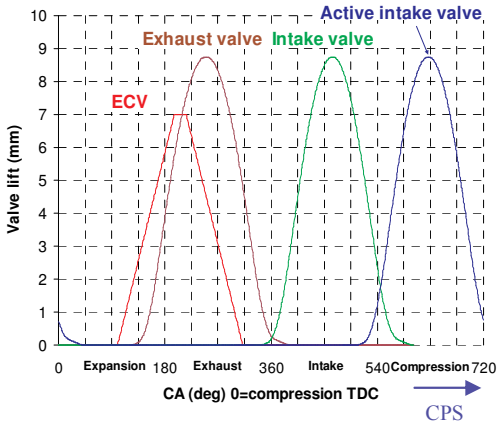
Energy capture and storage ability
Compressor mode – using CPS + ECV





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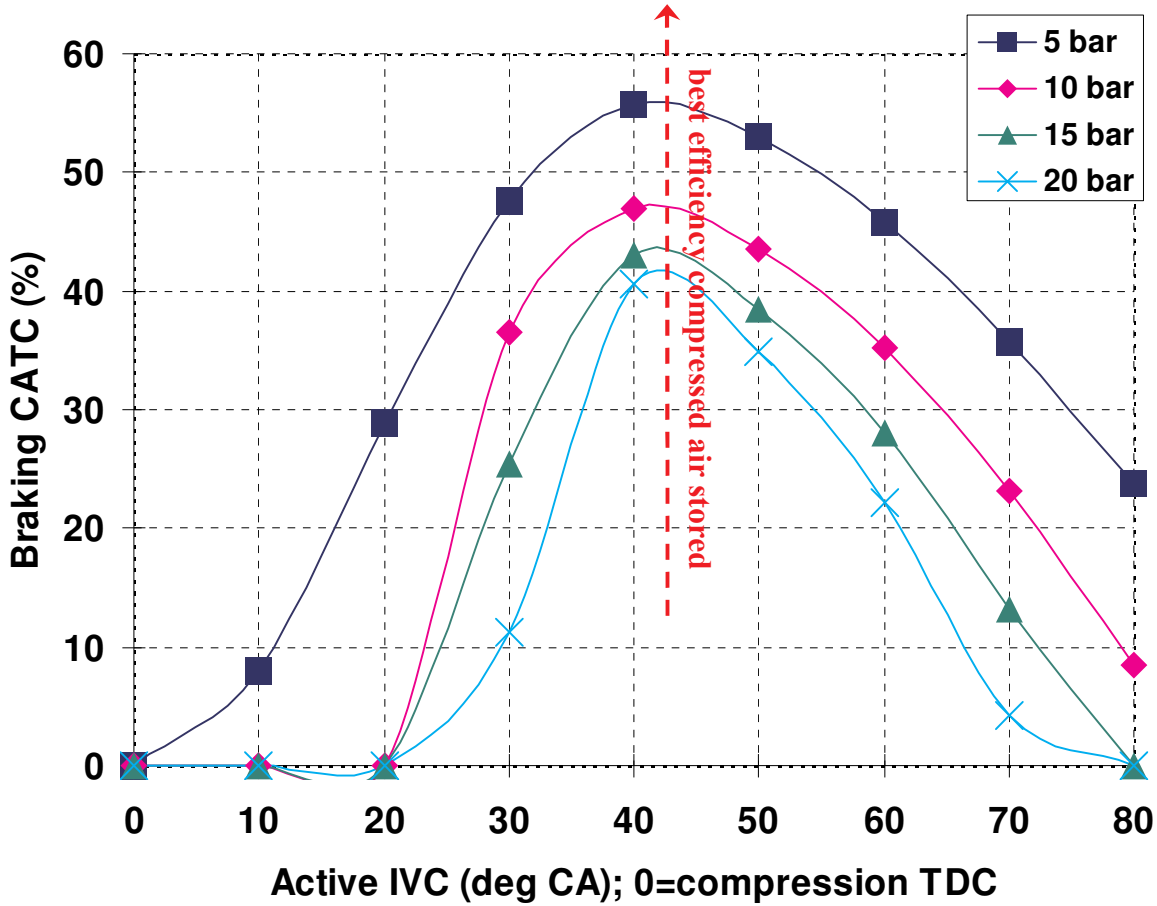
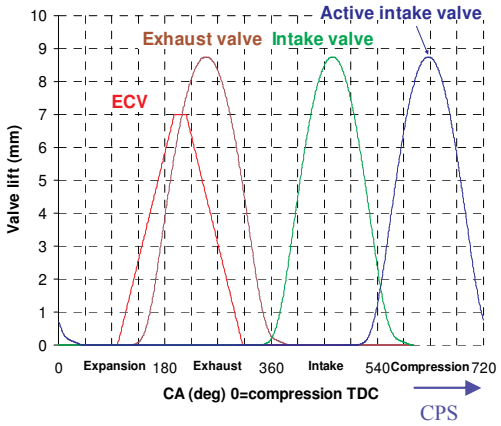
Compressed air stored
Compressor mode – using CPS + ECV





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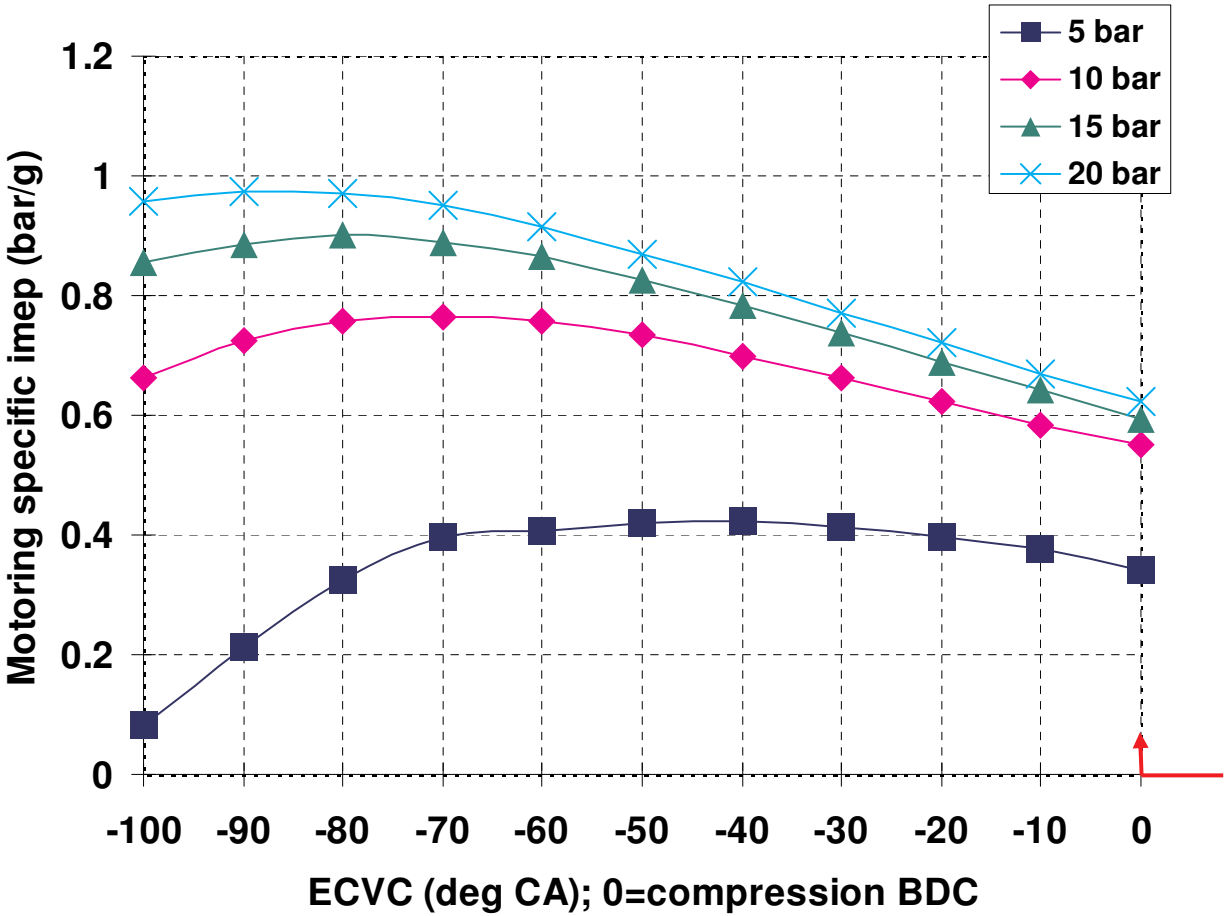
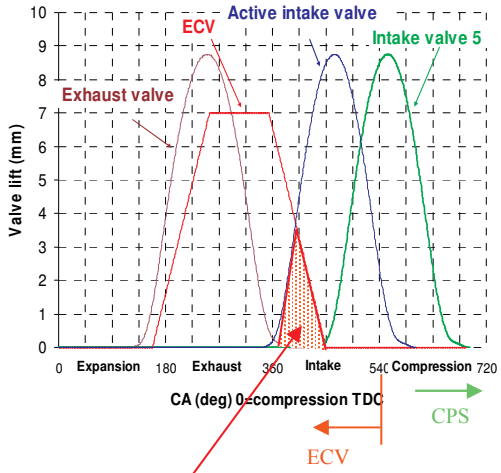
Energy re-use ability
Expander mode – using ECV + CPS





metered air admission for
thermodynakic expansion
and efficient motoring IMEP

stop/start
specific IMEP

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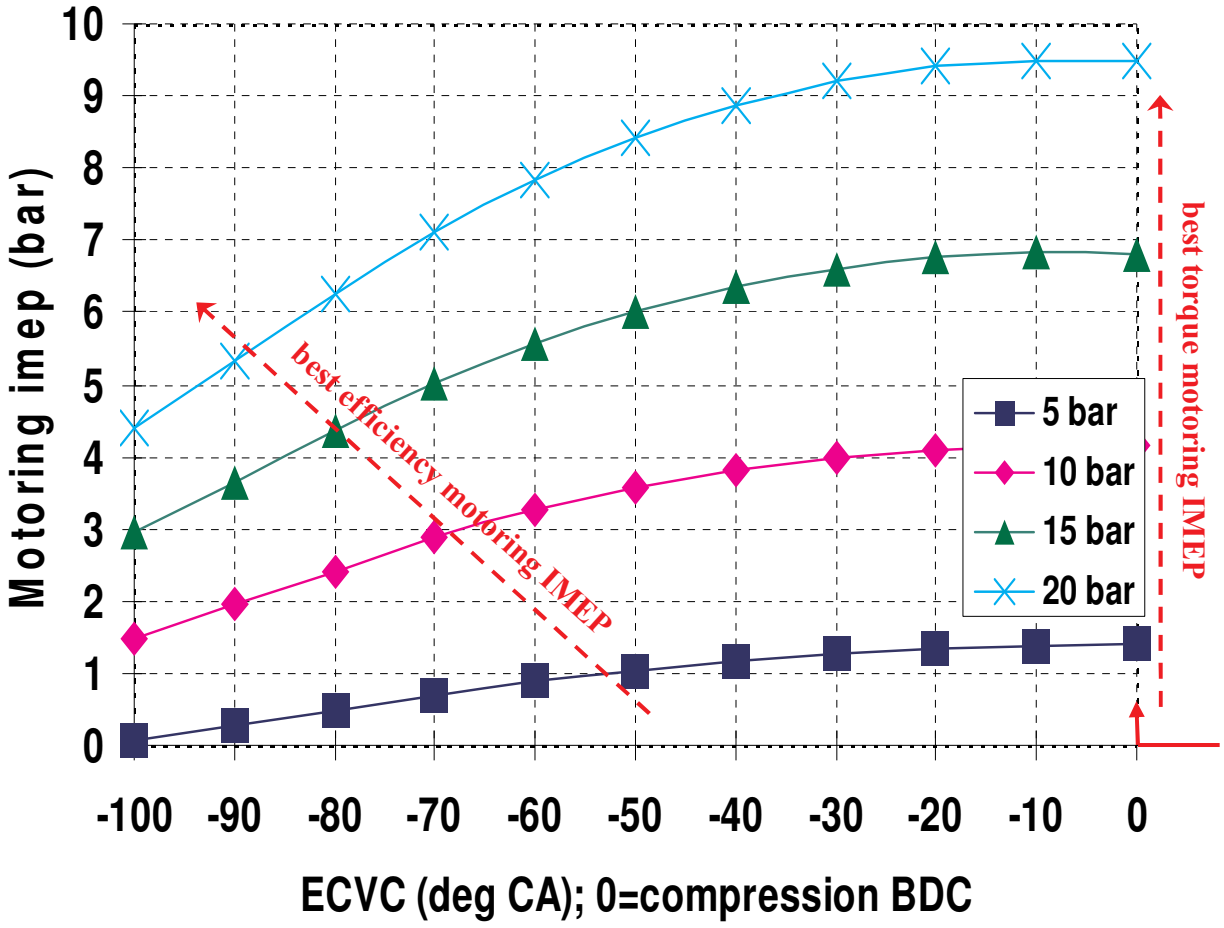
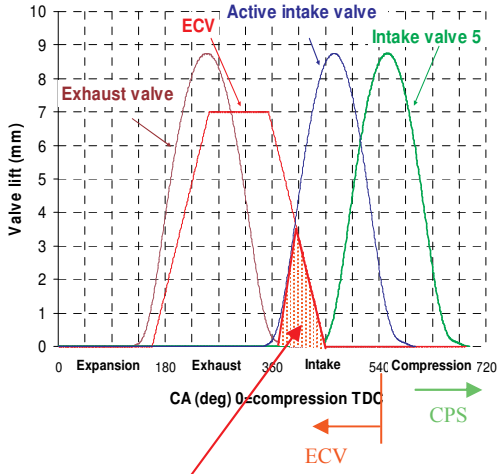
Motoring IMEP
Expander mode – using ECV + CPS





metered air admission for
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stop/start
motoring IMEP

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Duty Cycle of a City Bus

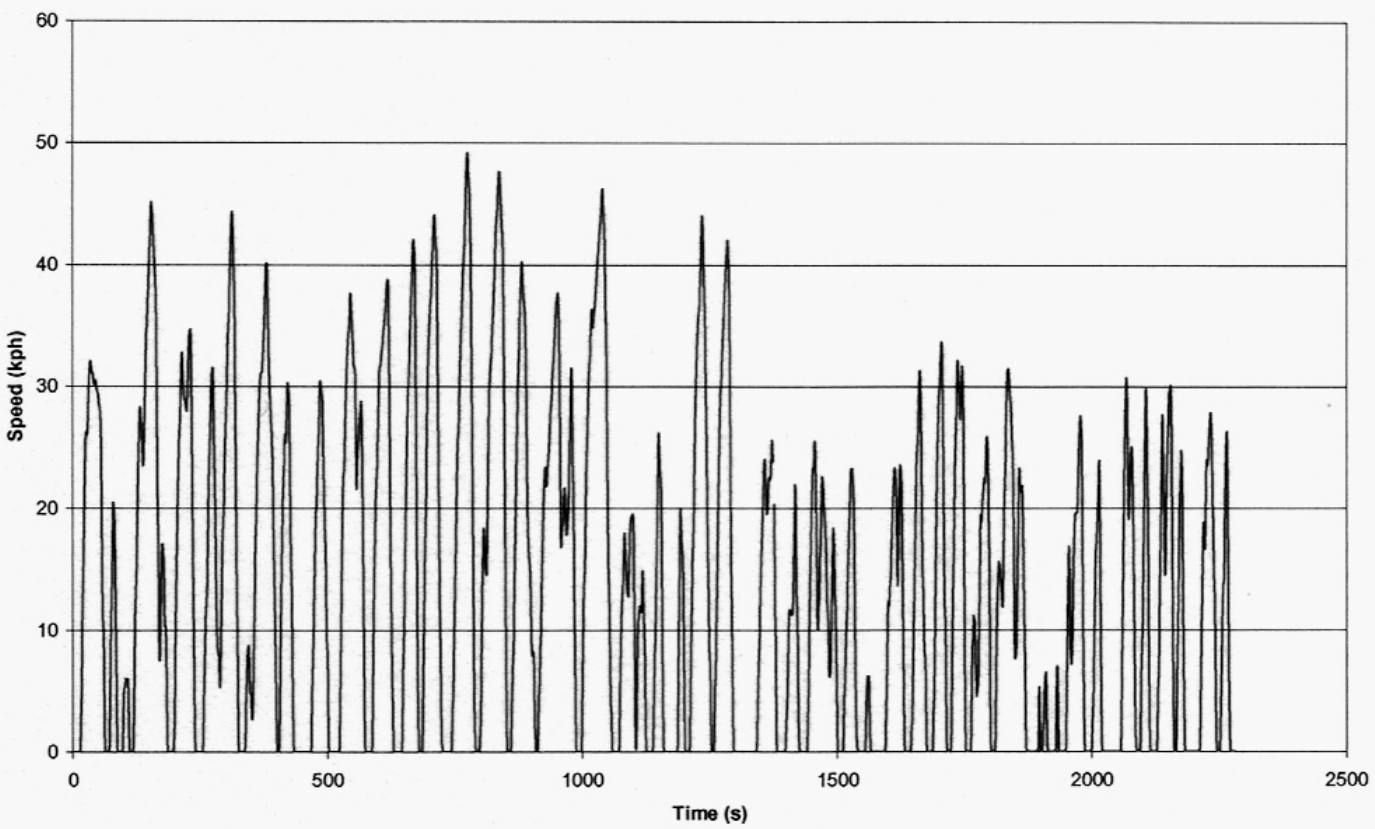

Figure2. 2 - Speed-Time Graph for London Route 159

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Air Hybrid is ideal for bus application

London Bus Route time utilisation: 24% idle stops, 70% accel/decel, 6% cruise

Stop/start operation gives the biggest fuel saving for a city bus

- Saves fuel at every bus stop by eliminating engine idle, i.e. switch off engine
- Focus on achieving high compressor efficiency to produce large quantities of compressed air for restarting the engine, using braking energy during decels
- Engine can produce more compressed air than is needed for starting "for free" so that the air hybrid energy balance is completely self-sufficient for stop/starts
- Fuel saved is 100% for the total length of time the engine is switched off

Cruise gives only small fuel saving because of small time utilisation in the drive cycle

- It is worthwhile only with high air motor efficiency (engine in expander mode)
- Less cost-effective for bus operation, but other types of vehicles with more time utilisation for cruise during the drive cycle will benefit from high air motor efficiency

Acceleration gives no fuel saving because the engine cylinders will be in firing mode

- Expander mode cannot be used, but compressed air may be injected into the engine to eliminate turbo-lag

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Future Work

- Continue to explore the air hybrid VVT options for best compressor and expander efficiencies
- Target is to achieve regenerative efficiency of 30%
- VVT option with Hydraulic Valve Stop HVS could provide a very simple air hybrid system
- Carry out Drive Cycle Vehicle Simulation to predict fuel economy benefits from stop/starts and during cruises

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Summary

- Brunel Air Hybrid is best suited for city buses where the drive cycle has a lot of stop/starts
- Uses proven VVT system in engine valvetrain
- Retains standard vehicle transmission
- Adds little extra cost or weight
- Offers valuable fuel saving benefits

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