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Development of an external combustion engine

Encontech BV

Symposium on using bioliquids in engines and turbines in CHP applications
Tuscany Regional Office, Brussels, 8 November 2011

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Power generation from Biomass

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Objective

To develop engine components/engines that are tolerant towards the bio-liquids mixtures and the fast-pyrolysis oils

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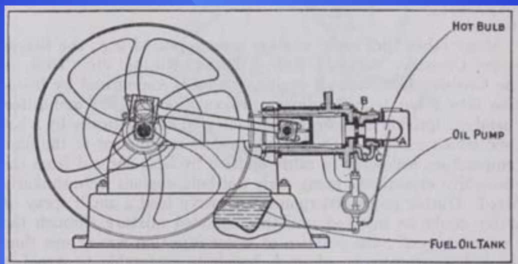
Approach

1. Modify hot bulb (or heavy-oil) engines



FROM CLERK AND BURLS, "GAS, PETROL AND OIL ENGINE" (LONGMANS, GREEN & CO.)
FIG. 10.—EARLY HORNSBY-AKROYD OIL ENGINE

A good choice for applications which involve poor-burning fuels and requiring a steady state power output

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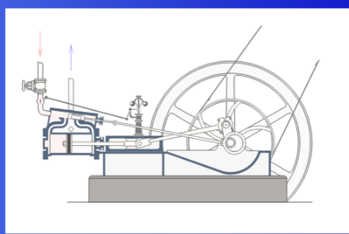
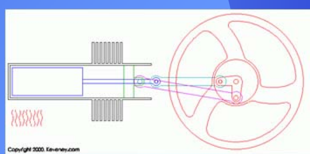
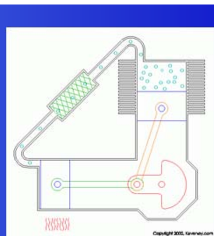
Approach

2. Modify external combustion engines: steam piston engines and turbines, Stirling engines

1. Fuel flexibility (including biomass and biomass derived fuels and low-grade heat sources)
2. Low emissions
3. Low noise







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ECT external combustion engines

1. Stirling/Manson type single-piston engine

2. Steam or Rankine cycle piston engine

3. New … engine

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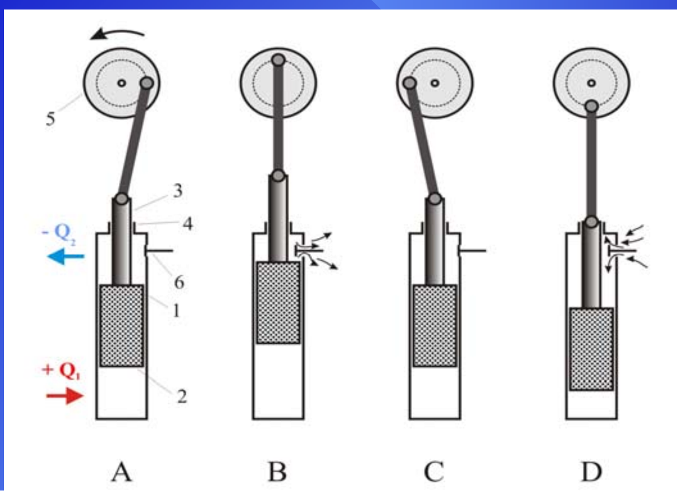
Stirling/Manson type engine principle



1. Cylinder
2. Displacer with regenerator
3. Piston
4. Piston seal
5. Crank gear with alternator

- One moving part !
- Variable amount of working fluid in the engine cylinder !

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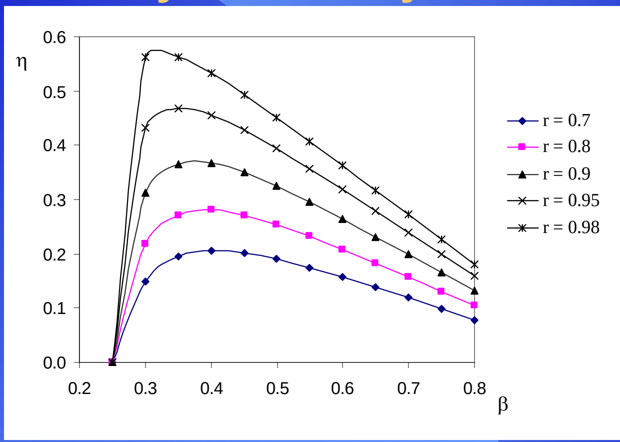
Thermodynamic analysis



η_{max} = 0.75

Thermodynamic efficiency of the engine as a function of geometrical parameter $\beta = (S-S_p)/S$ for different regeneration efficiencies and $T_C/T_H = 0.25$

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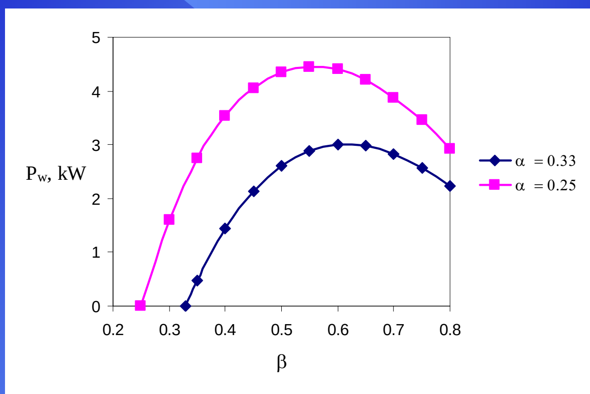
Thermodynamic analysis



Mechanical power engine as a function of geometrical parameter $\beta = (S-S_p)/S$ for different temperature ratios $\alpha = T_C/T_H = 0.25$ and 0.33; d = 40 mm; P = 100 bar, speed 1200 rpm.

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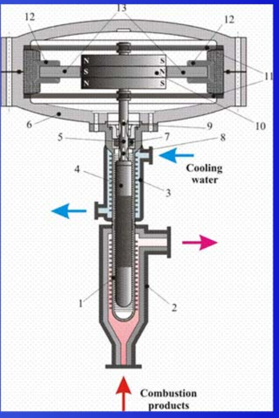
Detailed modeling (in co-operation with Russian researchers)



Design parameters

- Diameter of the cylinder, displacer and piston
- Mass of the piston and displacer
- Length of the cylinder and displacer, etc

Operating parameters

- Gas pressure in the engine, P_0
- Working fluid properties (molecular mass, ratio of C_p and C_v , thermal conductivity)
- Temperature of the heater and cooler

Main results

Crank gear-alternator combination is better than linear alternator

Energy losses can be substantially smaller than in Stirling engines

Fundamental study of heat regeneration for $T_H/T_C > 2$ is necessary

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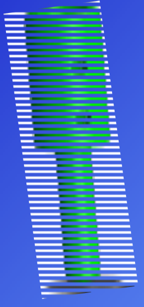
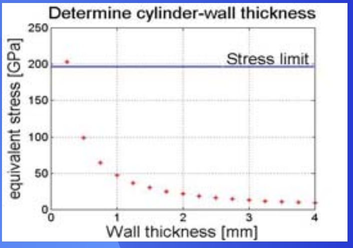
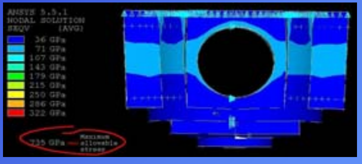
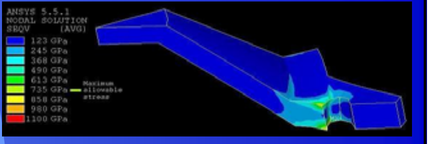
Strength analysis of the cylinder and crank case

Temperature of the cylinder 750 ^{0}C, pressure 100 bar









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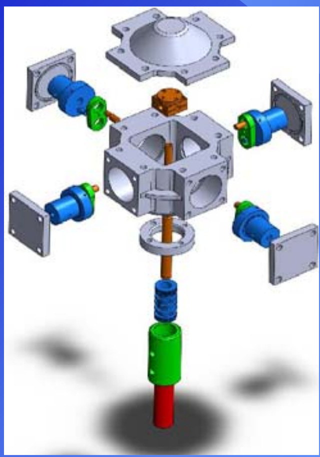
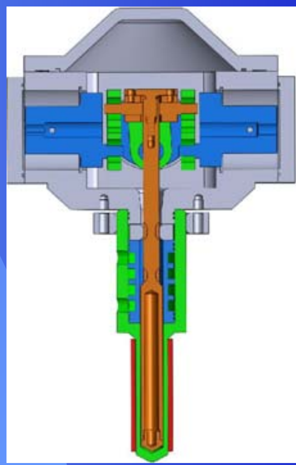
Engine assembly





the crank gear is oversized

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Main engine parts: cylinder and piston

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Crank gear with four crankshafts

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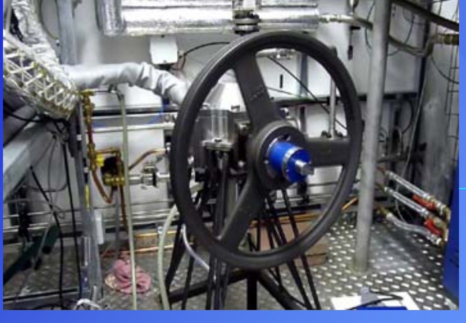
Stirling-Manson type engine
Test facilities, operating conditions and results



T_{heater} = 300 – 700 ^{0}C

Max heater power = 900 W

P_{design} = 100 bar

T_{cooler} = 15 ^{0}C

P = 1 - 30 bar

Main problem was the friction between the piston and seal

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Stirling/Manson engine in operation

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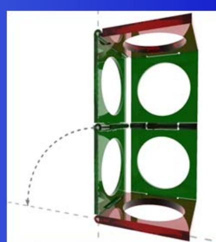
Novelties of the engine

1. ``Semi-closed`` thermodynamic cycle, pressurised engine.
2. Heat regeneration.
3. Sealing of the piston: new technical implementation of sliding valves.
4. Straight line kinematic scheme providing
   - ideal balancing
   - no side forces on the piston
   - no lubrication

Example straight line mechanism:
Sarrus linkage



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Advantages of the engine

Very simple design

- only one moving part; no valves, fuel injectors or spark ignition systems
- the only seal is located in the cold part of the engine (no problems with high-temperature sealing
- easy balancig (one moving part)

1. High thermal efficiency.
2. High power density.
3. Low cost.
4. Long maintenance interval.

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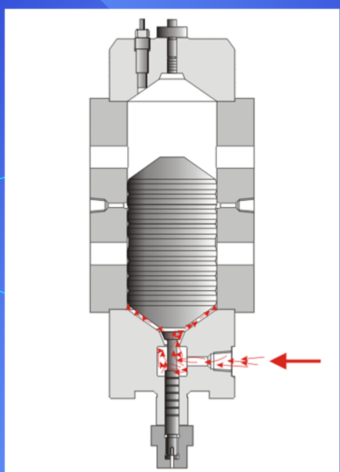
Steam or Rankine cycle engine principle



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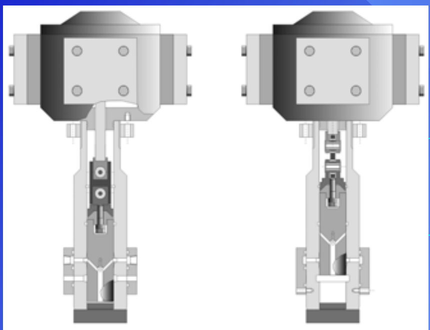
Steam or Rankine cycle engine principle



1. No piston rings and oil lubrication: crank gear with function of straight line mechanism and gas lubrication instead of oil lubricated guiding.
2. Self-aligning of piston is maintained by gas.
3. No conventional valves, the piston plays a role of a slide valve.
4. New materials with zero thermal expansion coefficient.
5. The piston is connected to double-hinge connecting rod.

Maintenance free engine!

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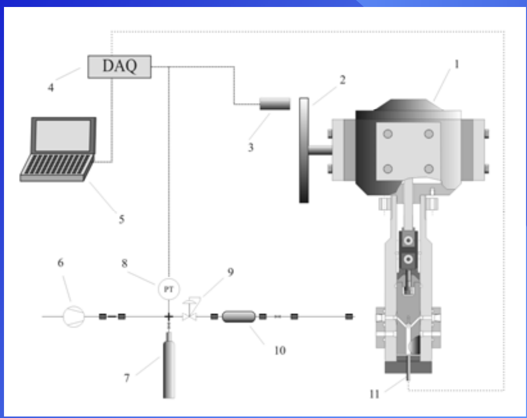
Steam engine test set-up



- Controlled driving air pressure up to 60 bar
- Driving air cylinder - 6 L, pressure up to 150 bar
- Receiver – 0.5 L
- Maximum allowed rotational speed – 2000 rpm
- Engine coupled with an alternator of 15 kW (not shown)

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Steam or Rankine cycle engine in operation

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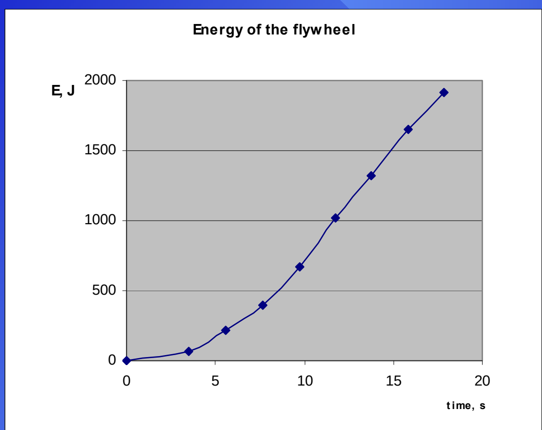
Results: steam engine power



$$E = \frac{J\omega^2}{2}, \qquad P = \frac{dE}{dt} = 160W$$

P_a = 10 – 20 bar

Compression = 3.2

Clearance = 17 10^{-6} m

P = 50 – 200 W

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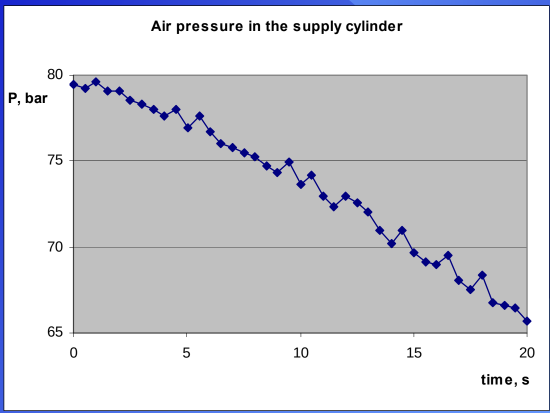
Results: steam engine mechanical efficiency



$$\eta = \frac{P}{E_{FRate}}, \quad E_{FRate} \square V_{cyl} \frac{dP_a}{dt}$$

$$\eta_{measured} \approx 40\%$$

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New ……heat engine. Advantages

- Very simple design
- Low costs
- High power density
- Any heat sources: 50 – 1000 °C
- Long lifetime and maintenance interval
- Easy scalable: 1 W – 1MW per cylinder

Expected to be ready for demonstration in December 2011

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Acknowledgement

This study has been carried out within the framework of the first Russian Federation – European Union cooperative project "Bioliquids-CHP", co-funded under the FP7 scheme from the European Commission (EC) and the Federal Agency for Science and Innovation (FASI) of the Russian Federation.

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Thank you!

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Rankine cycle engine principle

piston reciprocation.3gp

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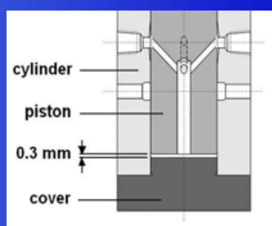
Further tests

Stirling type engine

1. Improvement of the regenerator and working fluid.

Rankine cycle based engine

1. Testing engine at different pressures of the driving gas and with different compression ratios.



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Combustion of pyrolysis oil in an external

Combustion of pyrolysis oil for application in a gas turbine
Co-operation between University of Twente, BioPlus Systems BV and BTG-BTL BV

Tested in a FLameless-OXidation (FLOX) burner in a Stirling CHP unit (SOLO 25 kWth)

Propane burner modified by an air pressure atomiser and a temperature control system. No erosion-corrosion problems - liquid velocity in the nozzle is low, (atomising air pressure 2 bar, liquid pressure – 0.9 bar).

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