LOW TEMPERATURE HEAT RECOVERY IN ENGINE COOLANT FOR STATIONARY AND ROAD TRANSPORT APPLICATIONS

PIERRE LEDUC, PASCAL SMAGUE – IFPEN
ARTHUR LEROUX, GABRIEL HENRY – ENOGIA
CONTENT

● Objective of the project

● Benefits of “low temperature approach”
  (heat recovery in the engine coolant)

● Case study:
  ● Passenger car
  ● Long haul truck

● Conclusion
OBJECTIVE OF THE PROJECT

TARGET:

- Joint project of IFPEN and ENOGIA to develop ORC turbine components for heavy truck and passenger car industry

CONTEXT:

- IFPEN: research and innovation center (energy, transport, environment)
- ENOGIA: “the small turbine ORC company”, ORC manufacturer

TECHNICAL APPROACH:

- Waste Heat Recovery (WHR) in the coolant circuit of the vehicle
**BENEFITS FROM ENGINE COOLANT WHR**

**In comparison to WHR in the exhaust gas or in the EGR:**
- No additional heat to evacuate (from vehicle point of view)
- No contact of the ORC with the exhaust gas
  => No need for material compatible with exhaust corrosive matter
- No parts of the ORC at temperature higher than 100°C (373 K)
  => No costly, high-temperature material
- Evaporator:
  - Integrated into the engine cooling circuit
    => No engine exhaust back pressure
    => No risk of evaporator fouling
  - Hot source in liquid form => compact evaporator
  - No hot spot => no risk of damaging the working fluid
    (Even in the case of a malfunctioning of the ORC pump)
- Stable temperature of the hot source => easier control
  => Safer control of superheating
- In combination with a well-chosen and non-flammable working fluid:
  - ORC running pressure remains low => lightweight sizing of the parts
  - Low-temperature, low-pressure running conditions => safe system

**SUSTAINABLE MOBILITY**
Objective of the project

Benefits of low temperature approach
(heat recovery in the coolant)

Case study:

Passenger car

Long haul truck

Conclusion
For vehicle speeds from 50 to 90 km/h, heat dissipation in the coolant is about 5 to 10 kWth.

For the future, the advent of efficient thermomanagement strategies will even increase coolant temperature up to 105°C.

=> higher grade heat source for WHR

### Example of heat loss in the coolant of a passenger car

<table>
<thead>
<tr>
<th>Vehicle speed (km/h - mph)</th>
<th>Engine power (kW)</th>
<th>Heat flux dissipated at radiator (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 / 19</td>
<td>1.0</td>
<td>3.7</td>
</tr>
<tr>
<td>50 / 31</td>
<td>2.3</td>
<td>5.6</td>
</tr>
<tr>
<td>70 / 43</td>
<td>4.8</td>
<td>7.1</td>
</tr>
<tr>
<td>90 / 56</td>
<td>8.7</td>
<td>10</td>
</tr>
<tr>
<td>120 / 75</td>
<td>18.5</td>
<td>12</td>
</tr>
</tbody>
</table>

Measurements on a Ford Focus EcoBoost 1.0 L at IFPEN chassis dyno
Using vehicle measurements as input data, a system simulator has been used to:

- Identify suitable working fluids
- Estimate ORC performance

**Hypothesis for calculation:**
- ORC cycle: 85 / 40°C (358 / 313 K)
- Superheating and subcooling = 5 K
- Turbogenerator efficiency = 0.54
- Pump efficiency = 0.15

<table>
<thead>
<tr>
<th>Working fluid</th>
<th>Formula</th>
<th>Fluid pressure hp / lp (Mpa)</th>
<th>Fluid mass flow (kg/s)</th>
<th>Turbine Power (W)</th>
<th>Net ORC power (W)</th>
<th>ORC power / engine power (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R245fa</td>
<td>C₃H₃F₅</td>
<td>0.80 / 0.29</td>
<td>0.03</td>
<td>330</td>
<td>218</td>
<td>4.6 %</td>
</tr>
<tr>
<td>HFE 7000</td>
<td>C₄H₃F₇O</td>
<td>0.40 / 0.14</td>
<td>0.04</td>
<td>300</td>
<td>233</td>
<td>4.9 %</td>
</tr>
<tr>
<td>NOVEC 649</td>
<td>C₆F₁₂O</td>
<td>0.27 / 0.09</td>
<td>0.06</td>
<td>280</td>
<td>221</td>
<td>4.6 %</td>
</tr>
</tbody>
</table>

**Computed ORC performance for different working fluids**

*(Vehicle running point: 70 km/h - 43 mph)*
ORC TURBO-GENERATOR FOR PASSENGER CAR

**Design inputs**
- Compact, no external lube
- Payback in 60,000 km
- Easy to plug-in and safe working fluid

**Main features**
- Heat recovery in the engine coolant
- Electrical output turbine
- NOVEC 649, max 3 bar, 90°C

**Dimensions**
- 130 mm length
- 95 mm height

**Weight:** 2 kg
CONTENT

- Objective of the project
- Benefits of low temperature approach
  (heat recovery in the coolant)
- Case study:
  - Passenger car
  - Long haul truck
- Conclusion
HOT SOURCE POWER AVAILABILITY

HIGHWAY CRUISE RUNNING CONDITIONS

Thermal power in engine coolant (kW)

Engine power (@ crankshaft, kW)

11 L truck engine (experimental)
ORC TURBO-PUMP FOR HEAVY TRUCK

**Main features**
- Heat recovery in the engine coolant
- Purely-mechanical ORC turbo-pump
- Up to 3% fuel eco on highway cruise
- NOVEC 649, max 3 bar, 90°C

**Design inputs**
- 2 years payback
- Safe working fluid
- Compact, no external lube
- Upgradable to electrified solution

**Specifications**
- 8 kg, length = 290 mm, diam. = 150 mm
CONCLUSION

- IFPEN innovates for transport for 70 years...
- ...and ENOGIA is a specialist of small scale ORCs, especially at low temperature
  - 40 references, in 13 countries around the world
- Low temperature (90°C) ORC turbines are being developed, for the road transport industry
- Prototypes have been realized:
  - Purely mechanical, ORC turbo-pump for truck (belt driven)
  - Electric ORC turbo-generator for passenger car
  - Testing should start soon
- Heat recovery in engine coolant:
  - is lighter, cheaper and safer than in exhaust gas
  - should reduce fuel consumption by up to 3%
  - in the long term, could be combined with WHR in the exhaust to realize a kind of “ultimate waste heat recovery”

See the turbogenerator for passenger car at ENOGIA’s booth!
Thanks for your attention!

Find us on:

🌐 www.ifpenergiesnouvelles.com
🐦 @IFPENinnovation

pierre.leduc@ifpen.fr
arthur.leroux@enogia.com