Test results R-600 pilot heat pump

In paper industry

Rotterdam
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Project aim and partners
Project aim

Demonstrate that it is possible to build a 200 kW compression heat pump able to produce low pressure steam from 60°C waste heat from the drying section of a paper machine using components available in the market:

- Short development time
- Cost benefits from serial production, in particular:
  - Compressors already produced for cooling and refrigeration
  - R600 refrigerant
Project objectives

• Build, install and operate a 200 kW heat pump able to produce low pressure (1.8 bara) steam at Smurfit Kappa Roermond mill

• Operate the heat pump under various conditions

• Validate performance off design calculations
Project partners

- Smurfit Kappa: End-user, paper production
- IBK Groep: Heat pump supplier
- Bronswerk Heat Transfer: System integrator
- ECN: Research and project organiser
- ISPT: Facilitator
Project scope

- Design heat pump
- Design heat pump and process integration
- Built 200 kW pilot
  - Based on smallest compressor (Mayekawa) in range
  - Exact same concept upscalable to 2 MW
- Install heat pump at Smurfit Kappa Papier Roermond mill
- Execute experiments
- Involve process operators so they can gain hands-on experience with heat pump technology
Integration in paper production process
Paper production process

Residual heat ~60°C
~3,5 GJ/ton\textsubscript{paper}

Steam for:
• Drying 4..10 bara, ~3,5 GJ/ton\textsubscript{paper}
• Other users, ~0,4 GJ/ton\textsubscript{paper}
Composite Curves

Temperature [°C]

<table>
<thead>
<tr>
<th>Energy [GJ/ton paper]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<tr>
<td>2</td>
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</table>

- **ΔHcold**
  - 5 fresh air machine room
  - 6 process water
  - 7 circulation water
  - 8 fresh air pre and after dryer
  - 9 LP-steam steam box, starch
  - 10 HP-steam cyclinders

- **ΔHhot**
  - 1 sens. heat air pre and after dryer
  - 2 sens. and latent heat pre and after dryer
  - 3 sens. heat waste water
  - 4 sens. and latent heat mach. room air

Heat pump

pinch 80°C
process air dew point

ECN
Waste heat recovery heat exchanger
Location at in exhaust duct
R-600 Heat pump
R-600 Heat pump

Condenser

Suction gas heater

Process water heater

Expansion device

Evaporator

Condenser

Suction gas heater

Process water heater

Evaporator

Suction gas superheater

Compressor
Heat pump under construction
Heat pump at Smurfit Kappa
Performance calculations and Measurements
Performance Calculations

- External conditions given by end – user
- Assumption on:
  - Temperature differences (ΔT’s) over heat exchangers (3 K)
  - Compressor efficiencies (0.8)
  - Efficiency electric motor and speed control (0.95)
  - Compressed gas superheating (5 K)
  - Condensate sub-cooling (75° to expansion valve)

- Two COP’s:
  - COP_{steam}
  - COP_{steam + hot water}
Performance measurements

- External mass and energy balance of:
  - Condenser
  - Process water heater
  - Evaporator
  - Electricity compressor

- Internal (specific) mass and energy balance
  - Measured butane conditions and calculated specific enthalpy
# Results

<table>
<thead>
<tr>
<th>steam pressure [bar]</th>
<th>Measured COPsteam</th>
<th>Measured COPsteam + hot water</th>
<th>Calculated COPsteam</th>
<th>Calculated COPsteam + hot water</th>
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</table>

Tevap 54°C .. 55°C
Conclusions
Conclusions and next steps

• Conclusions
  – Pilot heat pump producing 1,5 bara steam was build and successfully demonstrated at Smurfit Kappa Roermond mill
  – Heat pump was operated stable at higher steam pressures up to 3,4 bara
  – Measured performances match well with calculated performances

• Next Steps
  – Follow up project to increase COP\textsubscript{steam} (2-stage compression, multiple heat sources) and to increase steam pressure up to 6 bara (Pentane);
  – Follow up project to reduce CapEx down to € 200 per kW\textsubscript{thermal};out
  – Preparations for full scale demonstration project ongoing.