Phase Change Slurries as heat transfer and storage fluids for cooling applications

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Content

- Prediction of the cooling market in europe
- What is a Phase Change Slurry
- Thermophysical and hydraulic properties
- Benefit for air conditioning
- Conclusion
Predicted power consumption for the EU

- 11 TWh in 1996
- 44 TWh in 2020
- Scenario: business as usual

Source (EERAC-Study)
example: cold market in Italy

- EU Study (EERAC) 1996: four times the floor area conditioned in 2020 (for offices: 27% in EU, 80% USA, > 90% Japan)
- 2002 worldwide 15% of electricity for cold production (source: IIR)
Cooling on demand during warm days

- high ambient air temperatures -> high condensor temperature

Cooling is more efficient at night due to low night air temperatures

- storages are necessary to shift the cold from night to day

Sensible heat ("cold") storages require large temperature differences or big storage sizes

- Phase Change Material - storages offer high heat capacities within small temperature ranges
Power consumption of Chillers

Better efficiency at:
- low condensor temperatures
- high evaporator temperature
Function of Phase Change Materials (PCM)

- Phase change from solid to liquid and vice versa
- High heat capacity within the temperature range of melting and crystallisation
- Possible Materials
  - Gas hydrates
  - Salt hydrates
  - Paraffins

![Graph showing specific heat capacity vs. temperature for phase change materials.](image)
Micro-encapsulated Paraffin as PCM

- Paraffin can be micro-encapsulated economically
- The shell is made of PMMA
- Size of the capsules range between 1 and 20 μm
- Huge surface-volume relation
  - Heat transfer is limited by the surrounding’s heat conductivity
  - The capsules can be added to many different matrix materials
  - *Mixtures of a liquid carrier material and micro-capsules* are called *Phase Change Surries (PCS)*
PCS = mixture of a carrier fluid and a PCM

- **Carrier fluid**
  - water
  - Water-glycol mixtures
  - oils

- **PCM**
  - Micro-encapsulated paraffin
  - Paraffin emulsions
Heat capacities of PCS with different capsules fractions in water

- Objectives
  - high capsule fractions (high melting enthalpies)
  - low viscosities
  - small melting ranges
  - minor subcooling
  - high shear stability
  - minor separation
Viscosity as function of the capsule fraction in water

- Vand’s theory is valid for capsules > 50 μm
- PCS- capsules size ~ 4μm
  - higher viscosities than predicted by Vand
  - comparatively low viscosity up to 35%
  - experiments with 30% PCS (10 – 20 mPas)

![Graph showing viscosity as a function of capsule fraction]
Heat capacity of PCS compared to water

- Small melting ranges
  - better benefit to water
- Subcooling increases the temperature range of a PCS application

![Graph showing heat capacity comparison between PCS and water](image_url)
Subcooling of PCS

- Melting range is only 4 K
- End of melting is at 18°C
- End of solidification is at 11°C
  - necessary temperature range is 7 K
  - factor to water is only 2 (4 K -> 4)
Stability tests of PCS

- Test facility
  - conventional plate heat exchangers
  - centrifugal pumps
  - membran expansion vessels
  - breathers
  - valves

Heat can be calculated by mass flow, specific heat of water and temperature difference.
First results with 20 μm capsules (3 weeks of pumping)
Improvement with 5 µm capsules (6 month of pumping)
Experiment: pressure drops on heat exchanger compared to water

- Strong influence of temperature
- at 10°C ca. 20-25% higher than water
- at 20°C ca. 10-15% higher than water
Transferred heat

- 80 kg/h
  - Water 800W
  - PCS 1500W
- 100 kg/h
  - Water 1000W
  - PCS 2100W

![Graph showing transferred heat vs mass flow]
Cost reduction by better chiller efficiencies

- low condenser temperatures due to cool night temperatures
- higher evaporator temperatures due to small melting ranges and high storage capacities at temperature levels close to the target temperatures
Application with PCS as storage material

- Operation of chillers at night ➔ lower condensor temperatures
- PCS as heat transfer fluid ➔ higher evaporator temperatures and smaller storage sizes

➔ lower investment costs? Price of the PCS
➔ less operation costs by lower power consumption due to better efficiencies and lower mass flows.
Paraffin-Emulsions as PCM-Slurries

- only paraffin and an emulsifier, no capsule
- higher enthalpy
- cheaper
- lower viscosity?
- no long term stability-test up to now
- separation?
- Subcooling?

- Project funded by the german ministry of economics (BMWA) (hopefully part of annex18)
Conclusion

- The rising cooling market require new techniques to increase the efficiency of cooling for air conditioning.
- PCS offer the possibility to store heat at small temperature ranges close to the target temperatures needed for air conditioning.
- Decoupling of cold generation and cold demand is possible, also with small storage sizes.
- Increasing the capacity of installed systems just by changing the fluid.

- Improvements concerning subcooling are still necessary.
Thank you for your Attention