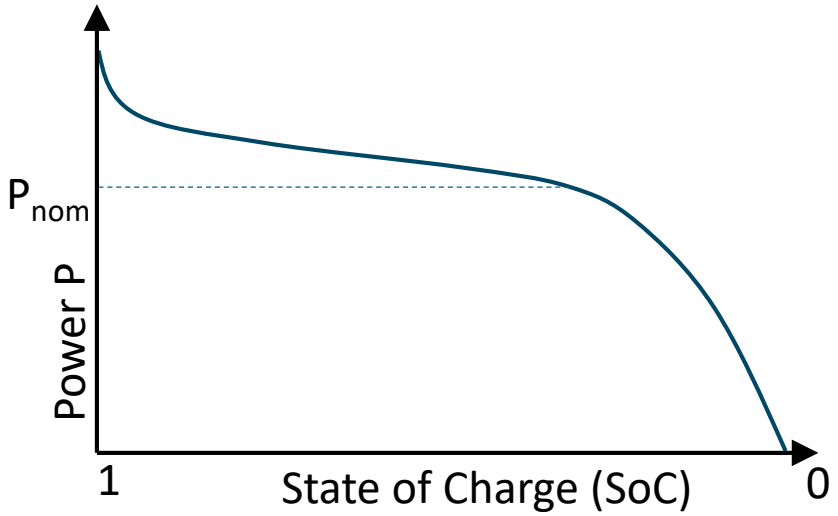
Evaluation of the scraping forces in active latent heat thermal energy storages

Jonas Tombrink, Alberto Egea Villarreal, Andrea Gutierrez

Latent Heat Thermal Energy Storages

Passive Systems

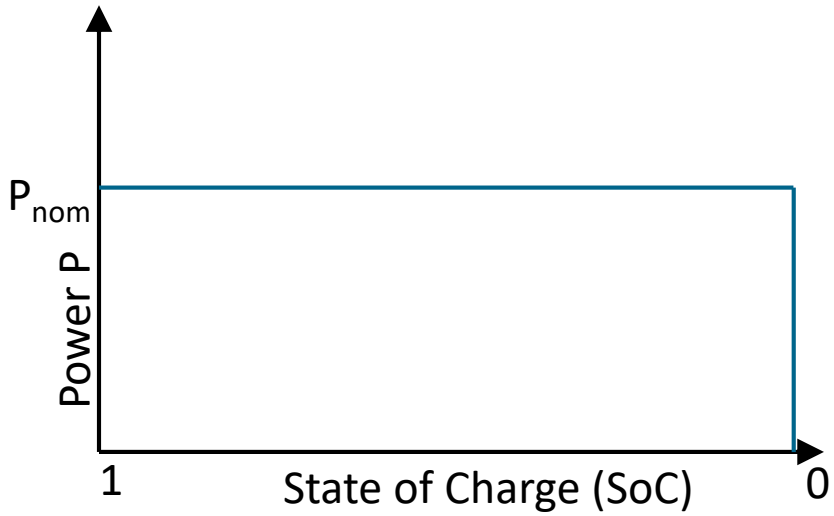
- No transportation of (solid) PCM



- No moving parts needed
- Predestined for high power systems

Active Systems

- Active transportation of (solid) PCM

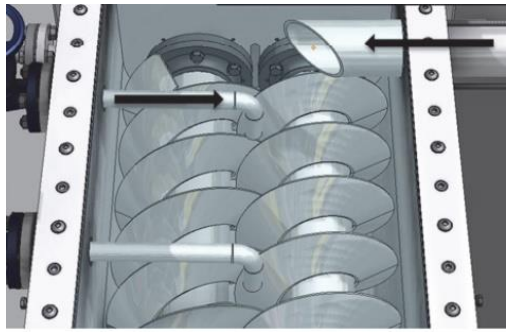


- Constant heat transfer
- Separation of power and capacity possible
- Predestined for high capacity systems

Active Latent Heat Thermal Energy Storages

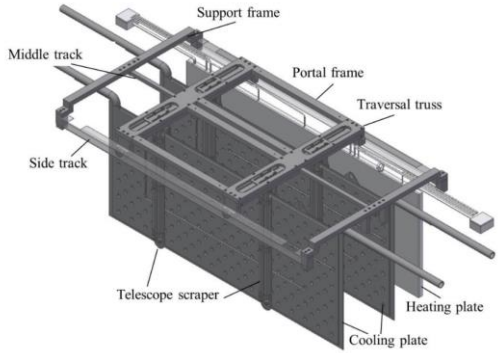
Selection of published Active Latent Heat Thermal Energy Storages

Screw heat exchanger



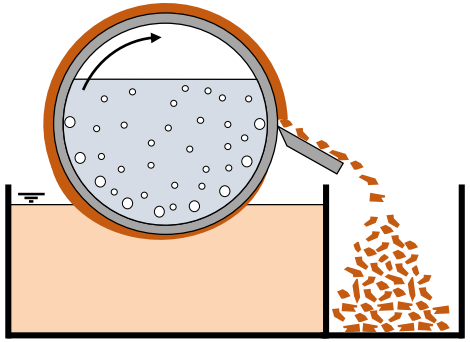
V. Zipf et al. (2015)

Scraped plate heat exchanger



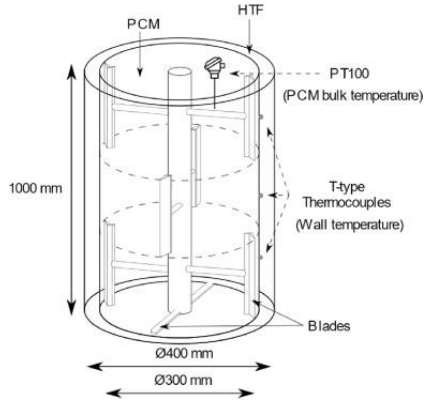
U. Nepustil et al. (2016)

Rotating drum heat exchanger



J. Tombrink et al. (2022)

Scraped vertical cylinder heat exchanger

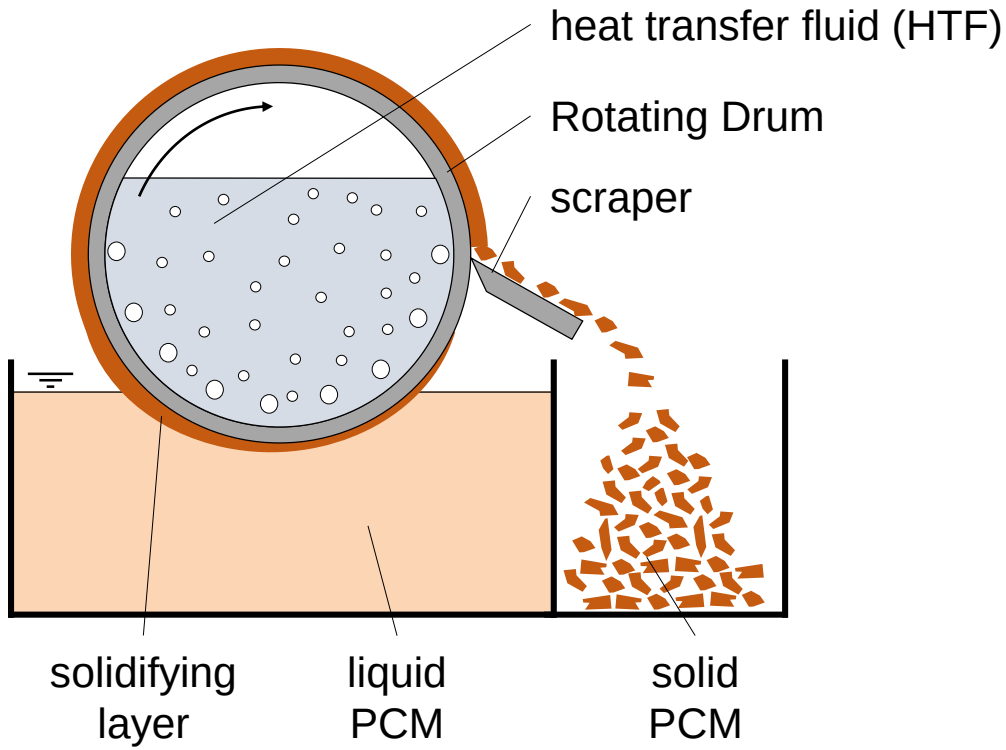


A. Egea et al. (2022)

- Almost constant heat transfer experimentally proven
- All concepts require electrical energy to remove the solid PCM from the surface

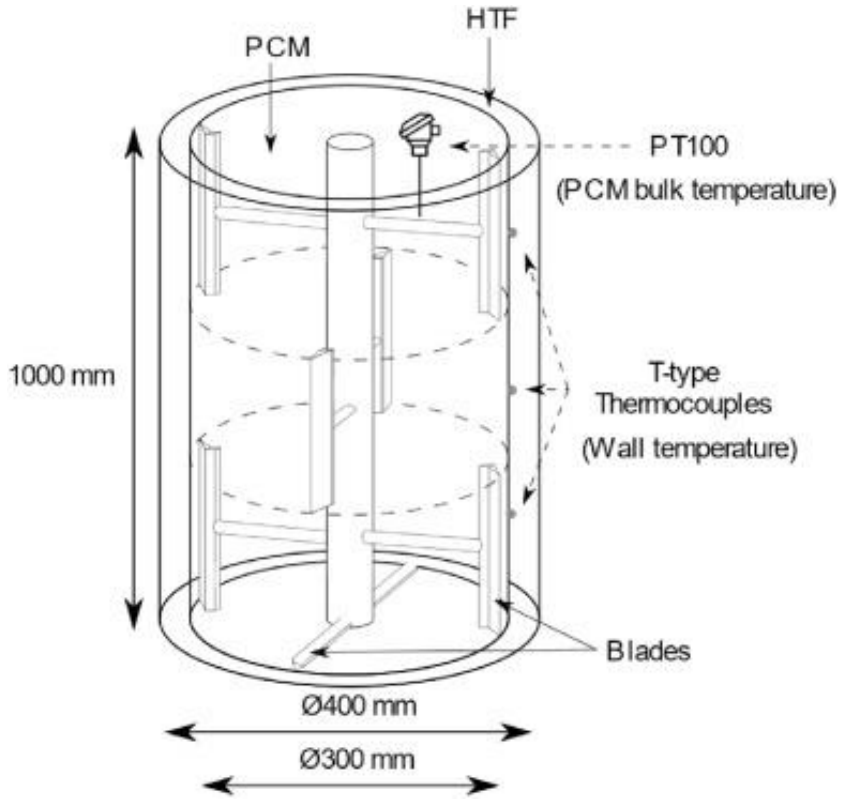
Rotating Drum Heat Exchanger

- Concept experimentally proven
  - liquid water as HTF
  - decanoic acid as PCM (T_m = 31.5°C)
- Constant heat transfer
- Heat transfer measured up to 1.7 kW
- Separation of power and capacity possible



Scraped vertical cylinder heat exchanger

- Concept experimentally proven
  - liquid water as HTF
  - Paraffin as PCM (T_m = 44-40 °C)
- Constant heat transfer during phase change
- Heat transfer measured up to 3.5 kW
- Reduction in solidification times (SM vs nSM)[1]

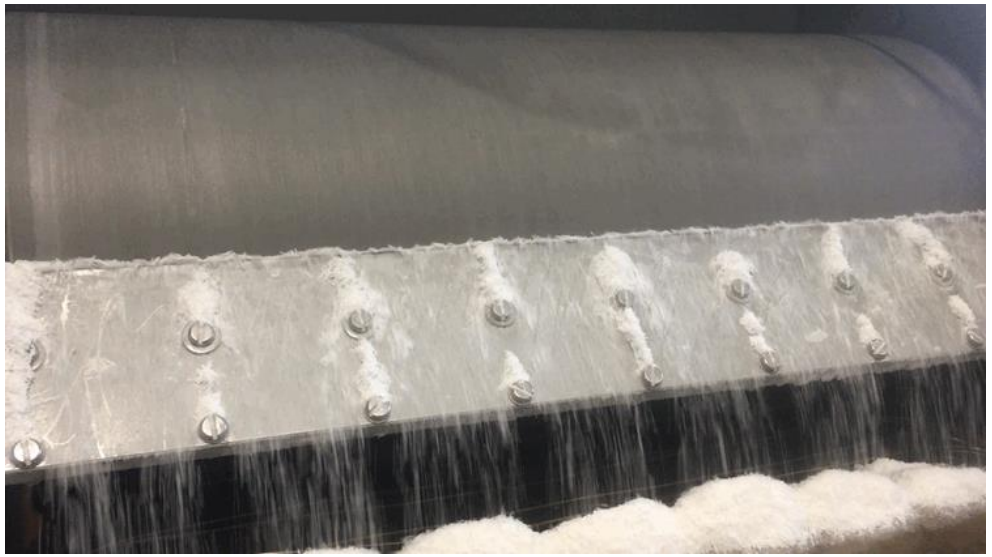


[1] SM = Scraping Mode
nSM = no Scraping Mode

Evaluation of the scraping forces in active latent heat thermal energy storages

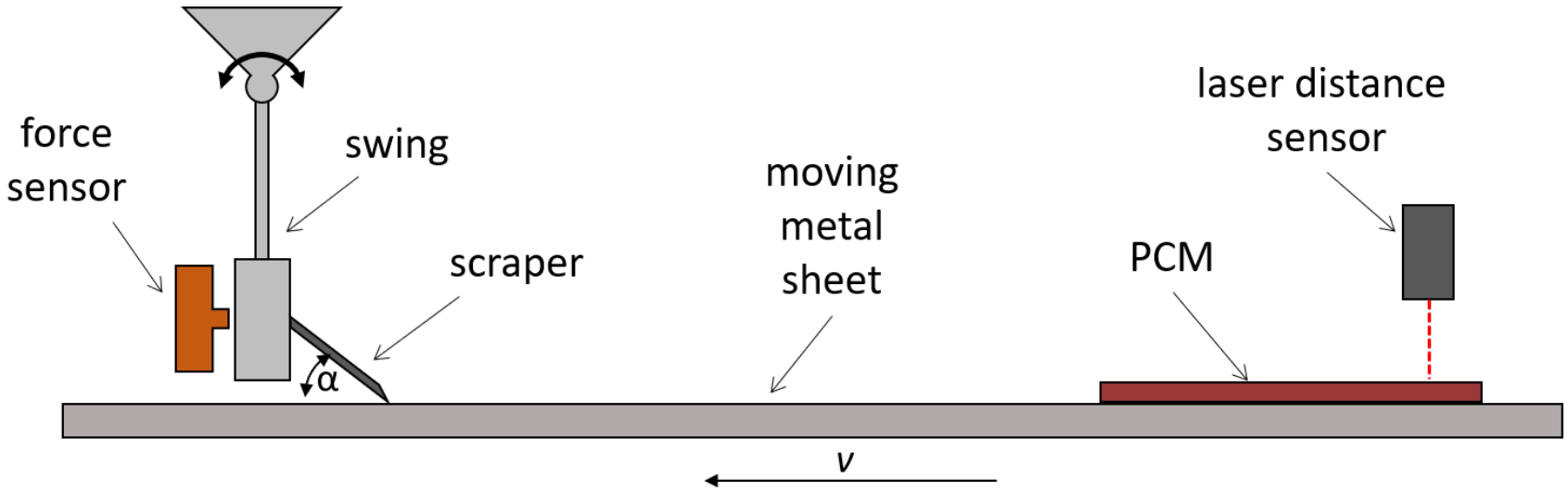
Knowledge required for:

- Design of future active latent heat thermal energy storages
- Estimation of required engine power
- Calculation of total “efficiency” of the storage
- Development of operational strategy in context of fluctuating energy supply



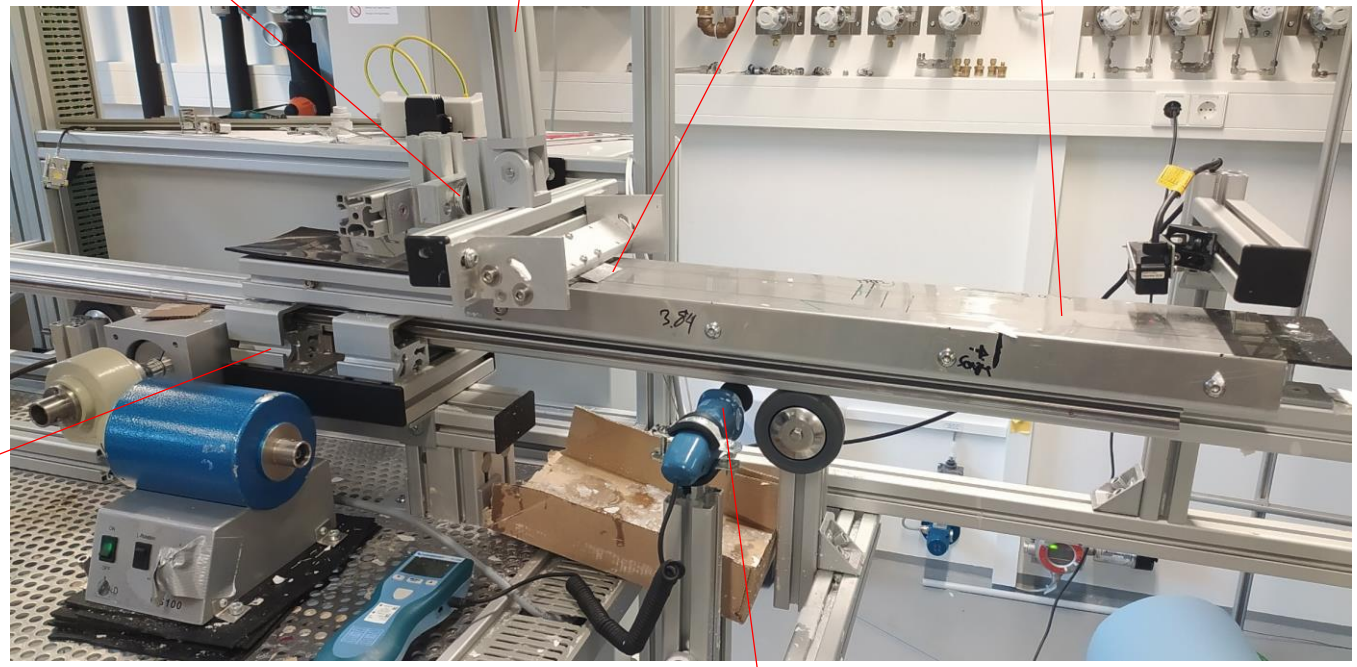
Experimental set-up

Visualization of the experimental set-up



Experimental Set-up

Picture of the experimental set-up



Examined PCMs

Decanoic Acid

- T_m = 31.5 °C
- used by Tombrink et al.

Paraffin RT44HC

- T_m = 41 - 44 °C
- used by Egea et al.

Sodium Nitrate

- T_m = 306 °C
- proposed as high temperature PCM

Experimental Set-up

Videos of the experiments

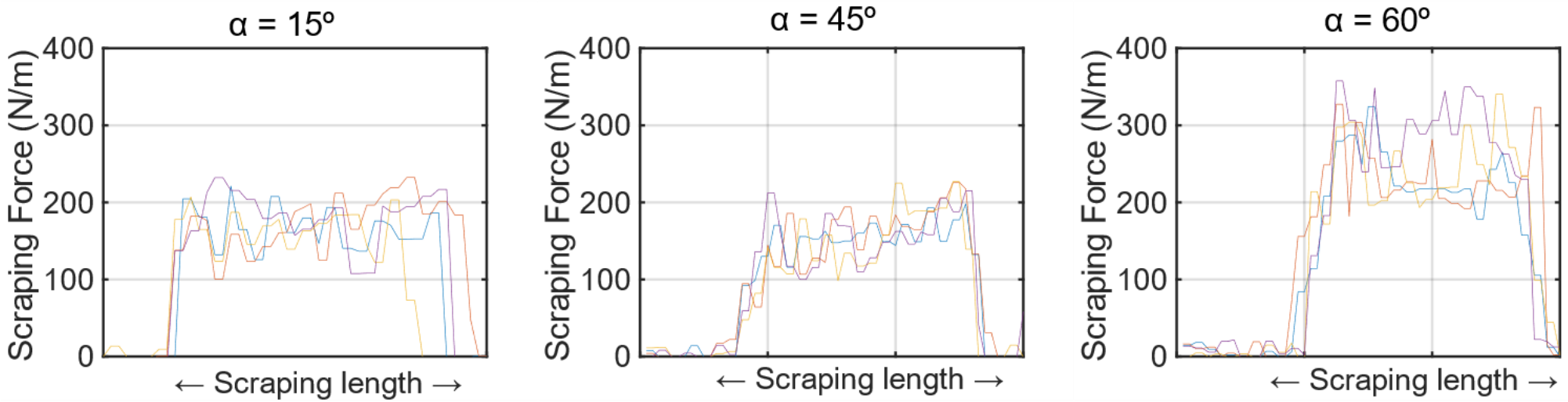
Decanoic Acid

Paraffin RT44CH

Experimental results

Velocity: 0,7 m/s
PCM Temperature: 31,5 – 30 ºC
PCM Thickness: 0,35 – 0,5 mm

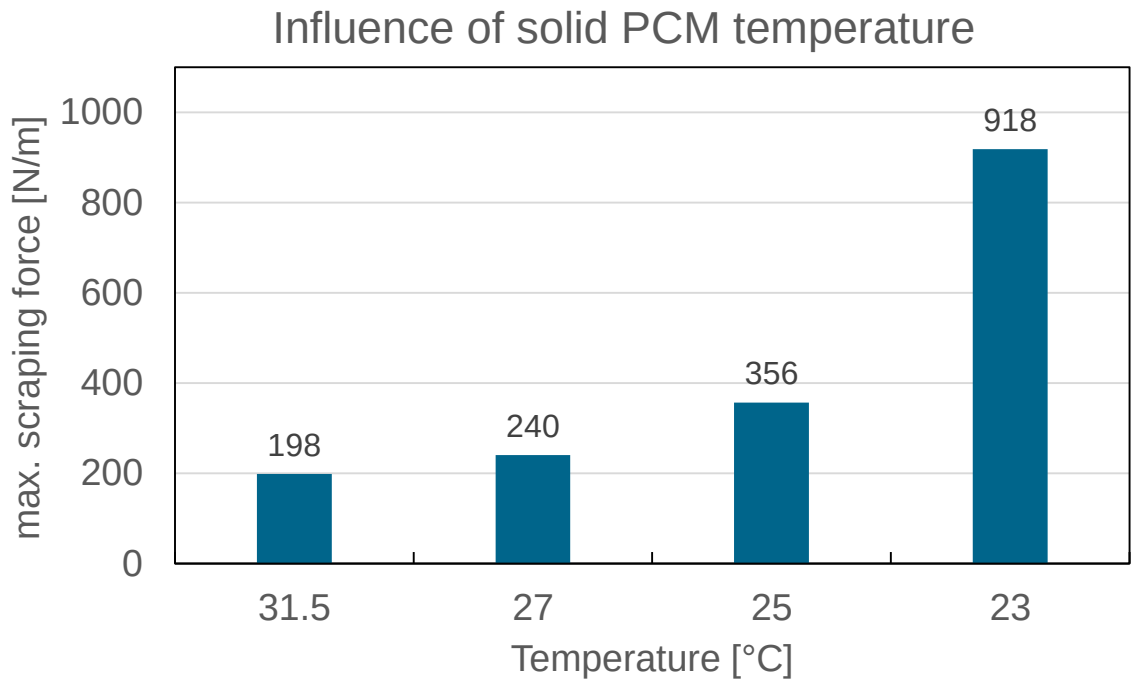
Decanoic Acid



- Almost constant force of 150 N/m for 15° and 45° angels
- Almost constant force of 250 N/m for 60° angel

Experimental results

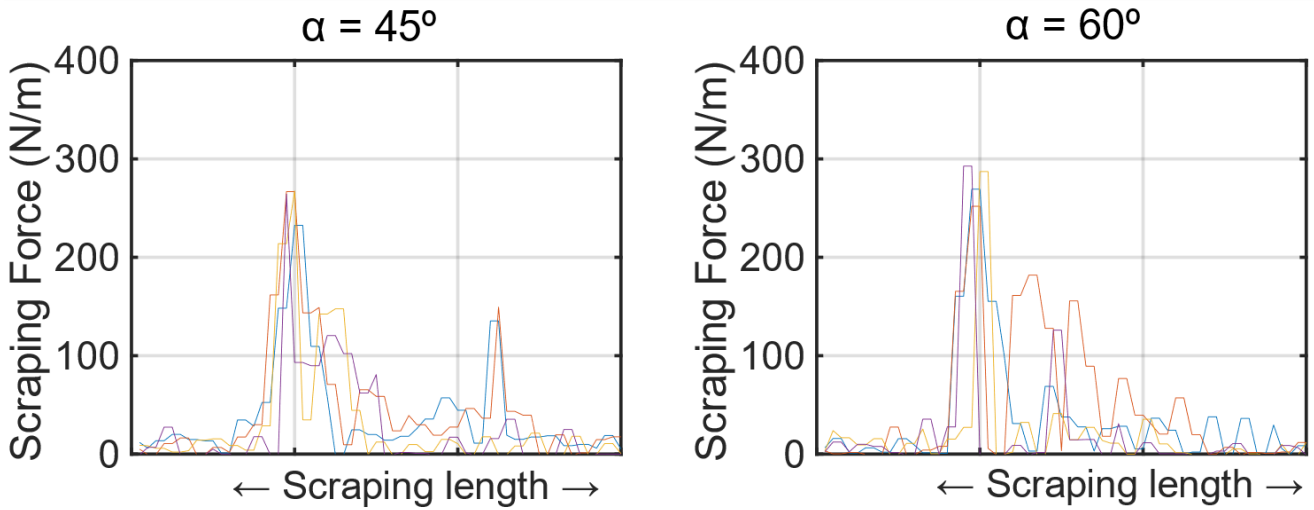
Decanoic Acid



Experimental results

Velocity:	0,75 m/s
PCM Temperature:	39 – 40,5 ºC
PCM Thickness:	0,7 – 0,85 mm

Paraffin RT44HC



- Highest force of 300 N/m at the beginning of scraping
- Decreasing force during further scraping

Experimental results

Sodium nitrate

Further investigations necessary

- No valid force measured
- Force below measurement accuracy
- Directional solidification of PCM might increase the connection

Discussion of results

Parasitic energy demand of the Rotating Drum Heat Exchanger

- Scraping length: 0.4 m
- Diameter of the drum: 0.184 m
- Rotational Speed: up to 25 1/min

$$M = F \cdot r \qquad P = M \cdot \omega$$

- Energy demand for scraping: 20 W
- Transferred Heat: 1.7 kW

- Parasitic energy for scraping: < 2%

Outlook

High temperature demonstrator

- Latent heat thermal energy storage based on the Rotating Drum Heat Exchanger
- Steam generation from $KNO_3/NaNO_3$ (eu)
- Steam pressure: 8 bar
- Thermal power: 100 kW
- Thermal capacity: 50 kW
- → Currently in commissioning

Thank you

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Impressum

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