Accumulation of heat in basalt at high temperatures in packed and fluidized bed

Karin RINDT
Karin.Edel@fs.cvut.cz

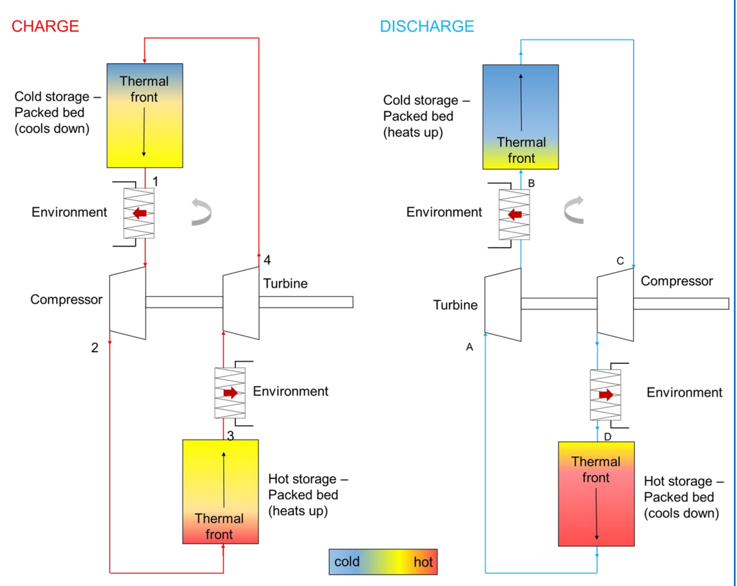
Supervisor: František HRDLIČKA
Supervisor specialist: Lukáš PILAŘ

Czech Technical University in Prague
Technická 4, Prague 6, 166 07 – Prague, Czech Republic

Faculty of Mechanical Engineering
Department of Energy Engineering

Renewable Energy Sources

- Naturally intermittent energy supply
- Time of supply ≠ Time of need
- Carnot-Battery storage
  - Longer storage durations possible
  - Geographically independent
  - Principle:
    1 Power to heat conversion
    2 Storage in hot (and cold) reservoirs
    3 Heat to power conversion



Basalt as storage material

Natural rock found plenty in nature
→ Low environmental impact

Rocks' wide temperature range
→ Versatile

Basalt
→ suitable properties for thermal energy storage

Cast basalt
→ also possible?
→ second-life after original intent
→ further lowering its impact + less waste

Natural basalt

Cast basalt

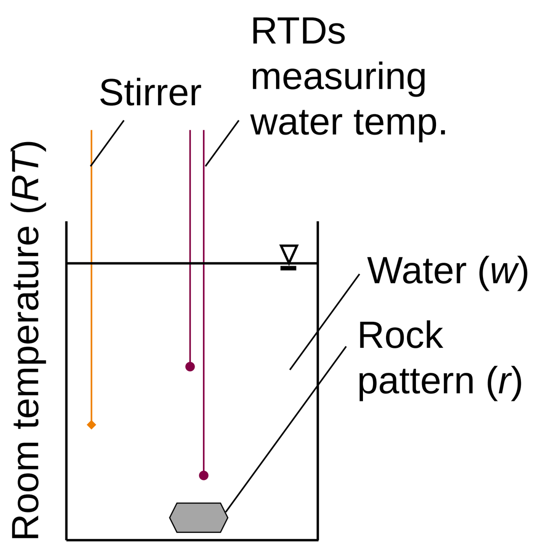
[KR3-6]

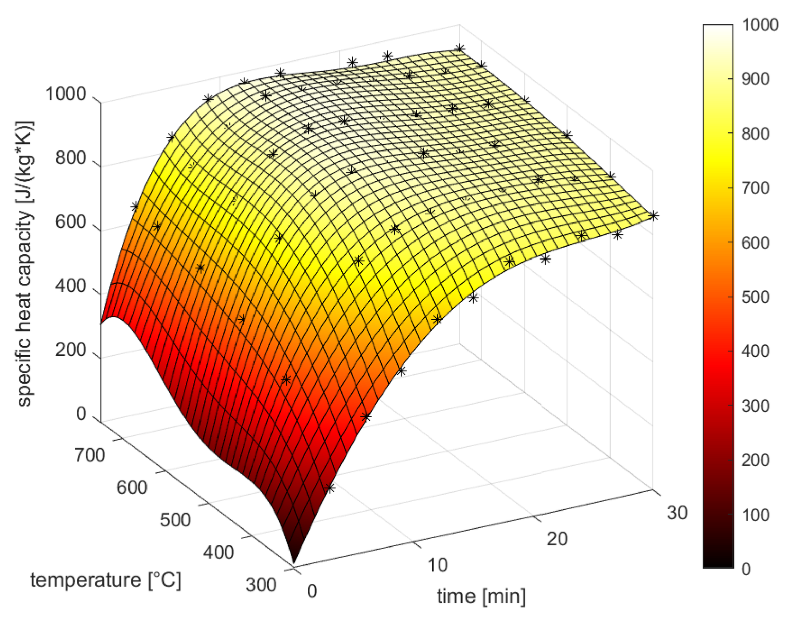
Behaviour of basalt

- Determination of heat capacity between 300 °C and 750 °C, over a heating period of 30 minutes.

$$c_{p,r,(x°C)} = \frac{\Delta Q_w + \Delta Q_{r,(RT)}}{m_r \cdot \Delta T_{r,(x°C)to(RT)}}$$

- The speed of reaching the full potential heat capacity is high and increases with higher temperatures
- Cast basalt reaches its potential faster than natural basalt
- Light degradation due to cycling





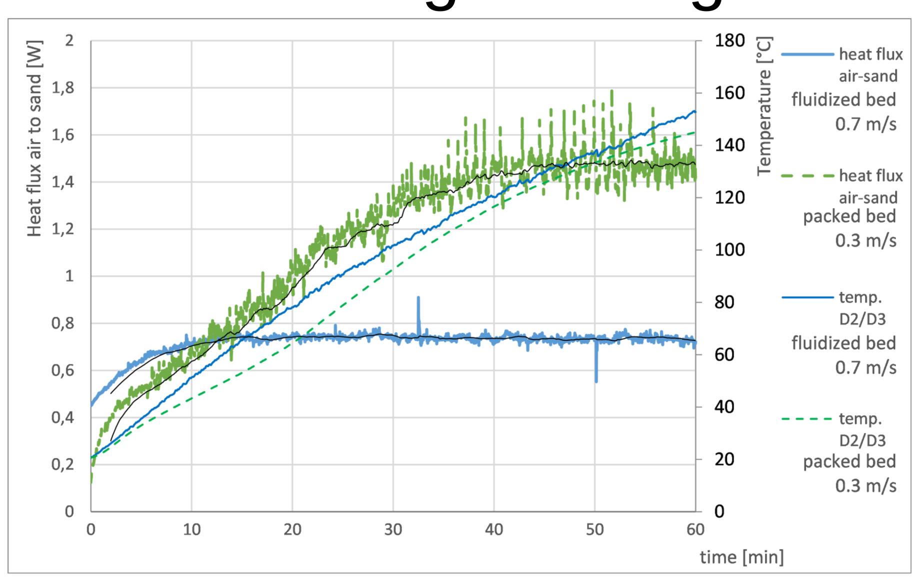
Mathematical model:
4th grade polynomial, fitted to the measurement data (*) using the method of least squares

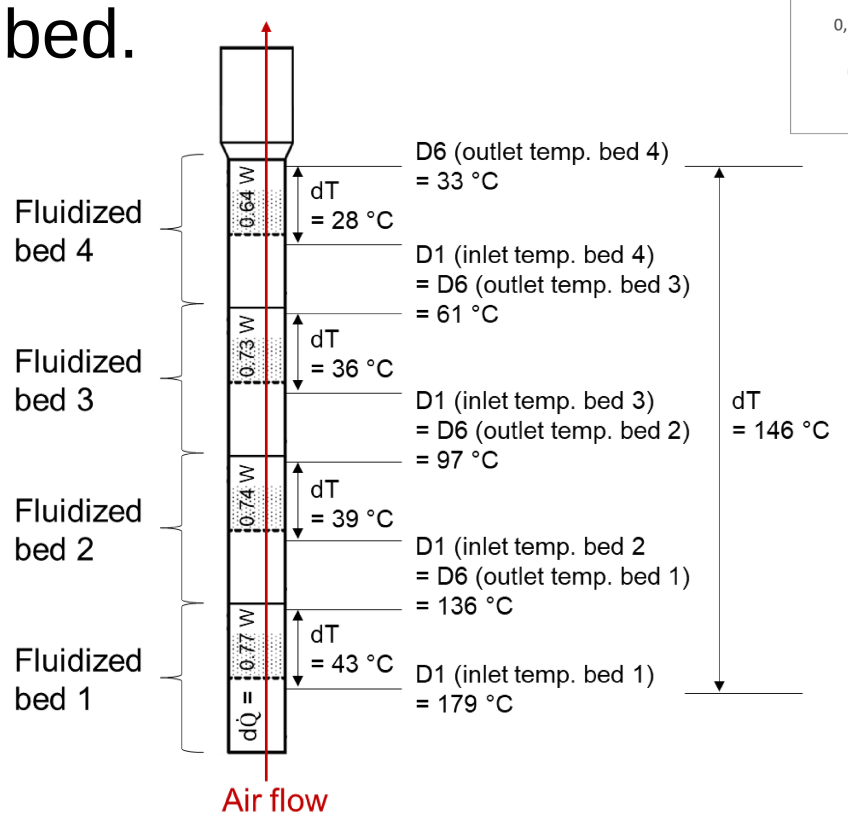
$$F(\alpha_{ij}) = \sum_{i=1}^{n}\sum_{j=1}^{m}\left(y_{ij} - P\left(t_i, T_j\right)\right)^2$$

[KR3,5]

Packed bed vs fluidized bed

A single storage vessel with a packed bed stores 57 % more energy within one hour than a single storage fluidized bed, because the heat flux increases (with the temperature) more for the packed than for the fluidized bed.





A multi-layered fluidized bed offers great flexibility and a better prediction of the output temperature, while always employing the maximal possible heat flux in the fluidized bed.

Experiments made with sand (easy to fluidize). Based on tests, basalt seems to be unsuitable for fluidization.

Conclusion

→ Basalt and cast basalt are very good thermal energy storage materials. Natural basalt is a material with low environmental impact. Waste cast basalt products can be recycled and re-purposed after the original.

→ Small changes of length, density and surface as well as a decrease in heat capacity due to heating and cycling.

→ A single vessel packed bed storage offers better thermal storage properties than a single fluidized storage vessel.

→ Multi-layered fluidized bed storage theoretically offers the benefits of packed and fluidized bed storage and more flexibility compared to packed bed. However, it is a more complicated set-up with probably low overall efficiency.

Publications of the Author

[KR1] Rindt, K.; Hrdlička, F.; Novotný, V. Preliminary prospects of a Carnot-battery based on a supercritical CO2 Brayton cycle. Acta Polytechnica, volume 61, no. 5, 2021: pp. 644–660, ISSN 1210-2709, doi: 10.14311/AP.2021.61.0644.

[KR2] EERA JP EEIP (group of authors including Rindt, K.). Industrial Thermal Energy Storage - The Transition to a Sustainable CO2 Neutral Industry [in print]. 2022.

[KR3] Rindt, K., Pilař, L., Hrdlička, F. Speed Of Reaching The Full Potential Heat Capacity Of A Basalt Product: Experimental Results. Proceedings of the International Renewable Energy Storage Conference 2021 (IRES 2021), 2022: pp. 136-142, ISSN 2589-4943, doi: 10.2991/ahe.k.220301.014.

[KR4] Edel, K., Pilař, L., Hrdlička, F. Thermodynamic Properties of Basalt and a Basalt Product for the Use in Energy Storage [Conference presentation]. Conference STC 2021, Prague, Czech Republic, 04.05.2021, Abstract available from: https://stc.fs.cvut.cz/history/2021/res d1 en.pdf.

[KR5] Rindt, K., Pilař, L., Hrdlička, F. Speed of reaching the full potential heat capacity of a basalt product: Mathematical model based on experimental results [Paper presented at conference]. ENERSTOCK 2021, Ljubljana, Slovenia, 09.-11.06.2021: pp. 1-7, Abstract available from: https://www.enerstock2021.org/images/enerstock 2021 book of abstracts FINAL v2.pdf.

[KR6] Pavlíková, M.; Pivák, A.; Edel, K. and Pavlík, Z. High-Temperature Dilatometric Measurement of Basalt [Paper presented at conference]. THERMOPHYSICS 2021, Dalesice, Czech Republic, 07.-09.09.2021: pp. 1-5.

CTU
CZECH TECHNICAL UNIVERSITY IN PRAGUE