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Dynamic Recycling of Waste Heat

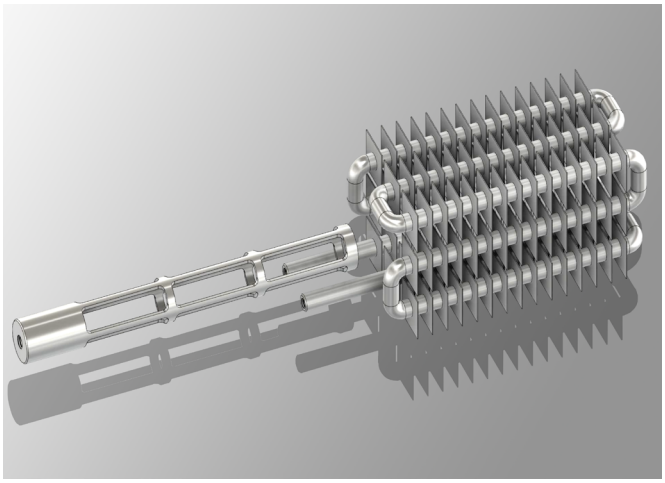
Store exhaust heat from 150-400 °C without losses, highly efficiently, compact

A few years ago, EU industry energy consumption accounted for 26 % of total final energy consumption in the EU, and usable waste heat in industry was 918 TWh per year, which corresponded to 29 % of industry energy consumption.* Often this waste heat falls in the range between 150° and 400° Celsius.

By temporarily storing and using this heat at lower temperature levels, a large portion of it could be put to good use, helping to reduce overall energy consumption and the CO_2 footprint.

A new module from the TU Wien is available for this purpose. It consists of a heat exchanger, fine pellets of inexpensive solid material, and an industrial reaction gas.

The module can be adapted to the needs of specific industrial sectors and companies. The evidence for this is provided by outstanding results with laboratory-scale prototypes.



Internal structure of the TU Wien module
with lance holder for reaction gas - used together with
fine pellets, it results in a highly dynamic heat accumulator

Objective

The aim of the research groups led by Prof. Peter Weinberger at the Institute of Applied Synthesis Chemistry and Prof. Andreas Werner at the Institute of Energy Technology and Thermodynamics was to develop a storage system that could withstand thousands of charging and discharging cycles with as little loss as possible, was technically easy to handle, and that is compact and cost-effective. Ideally, it should be able to react quickly, absorb waste heat at varying temperature levels, and release heat at many different, adjustable temperature levels in order to enable cascade use, which allows particularly high recycling rates for waste heat.

Solution

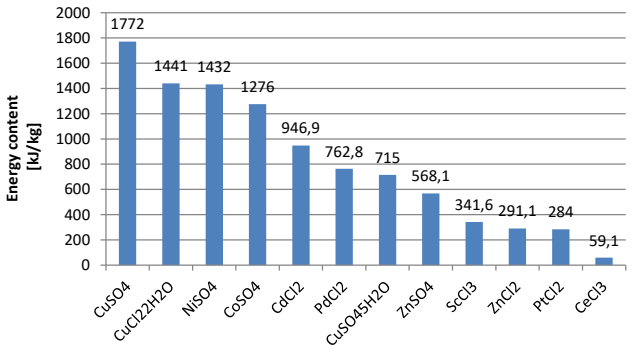
For this purpose, the researchers at TU Wien closely examined materials that were expected to undergo thermochemical reactions - such as those that occur when lime is „slaked“ with water, which spontaneously leads to heat generation. These were expected to enable the production of compact, solids-based systems for long loss-free storage with high energy density. The reaction kinetics of the solids can be specifically influenced by means of special structuring and spatial arrangement. Basic research has identified about 5,000 chemical reactions that can store heat in solids. In terms of storage density, reaction rate, cycle stability, technical handling and cost of the feedstocks, a dozen promising material combinations were identified.

Result

At 1.8 MJ/kg, copper sulfate ($CuSO_4$), which reacts completely reversibly with small amounts of ammonia (NH_3), exhibits the highest heat storage density. The $CuSO_4$ is applied to a porous and chemically inert carriersubstance and brought into contact with NH3 for heat release.

For regeneration, the ammoniate is heated by waste heat, which dissolves the NH3 from the solid again. A simple device which acts like a vacuum pump conveys the ammonia into a storage chamber, where it is kept ready for the next cycle.

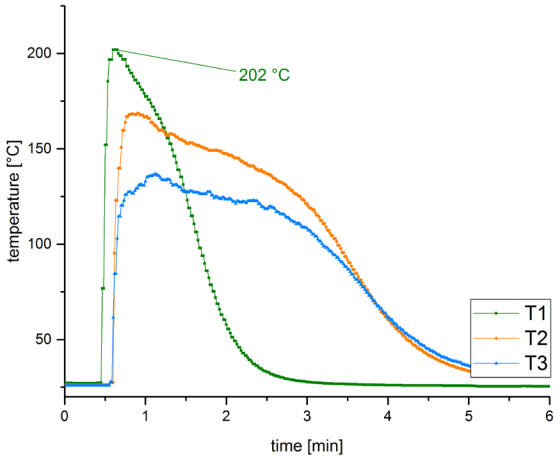
* *Bianchi, G., Panayiotou, G.P., Aresti, L. et al. Estimating the waste heat recovery in the European Union Industry. Energ. Ecol. Environ. 4, 211–221 (2019). (Springer Verlag) https://doi.org/10.1007/s40974-019-00132-7*



Storage density in relation to
the mass of a range of metal ammoniates

The system is highly dynamic and releases the heat at the highest temperature level, which can be up to over 300 °C, just a few seconds after the ammonia hits the solid. This temperature level, as well as that for heat absorption, can be specifically influenced by the structure and geometry of the carrier material, and by the selected heat transfer technology.

These flexible features allow the function of the storage module to be adapted to the cascade use case as desired.



Typical Temperature Curves
during the reaction of $CuSO_4$ with NH_3 –
dependent upon the geometry of the heat accumulator

Notes

Your Advantages

- first highly dynamic storage system for utilising waste heat between 150 °C and 400 °C
- lossless storage with high energy density of 1,8 MJ/kg
- highly dynamic heat release – less than one minute to peak temperature
- Supplies heat at a high temperature level of up to over 300 °C
- High cycle resistance
- adjustable temperature profiles for heat absorption and dissipation
- unique and cost-effective materials
- also suitable for long-term storage – over several months

At the TU Wien, several of our institutes offer a unique combination of methods for the exact determination of energy storage capacity - on the one hand, for material analysis and synthesis techniques, and on the other hand, for current process and production technology. This enables TU Wien to offer efficient adaptation of the basic module to desired industrial applications, as well as dimensioning of optimized highly dynamic heat storage systems - all from a single source.

Applications

- Waste heat recycling for the manufacturing industry in a wide range of sectors - from raw materials industries to foodstuffs - as well as for regional heating networks
- Storage of solar thermal energy for later use for power generation or heat supply
- Avoidance of cold starts in combustion engines in construction machinery, tractor units, shipping – through highly efficient preheating of catalysts and oil

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