

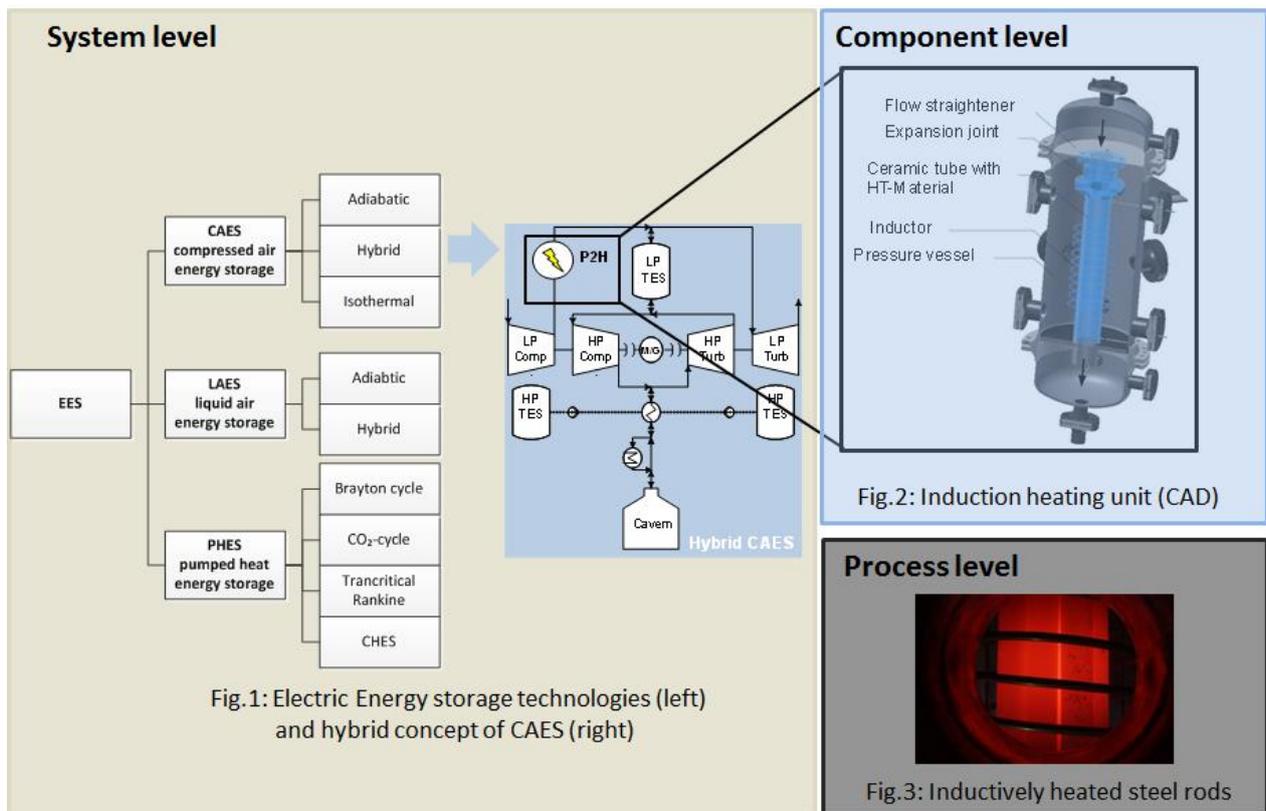
Identification of High-Temperature Materials for Energy-Efficient Power-to-Heat Integration in Compressed Air Energy Storage

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Graphical Abstract



Abstract

Utility-scale Electrical Energy Storage (EES) supports the expanding integration of intermittent renewable energy sources allowing a reliable and flexible supply of low-carbon or even zero-carbon electricity. Emerging EES technologies introduced in Fig. 1 (left) are considered adiabatic due to the implementation of thermal energy storage (TES) following the adiabatic compression and prior to the adiabatic expansion. Based on the Carnot heat pump cycle during charging and, when operating in reverse as a Carnot heat engine during discharging period, this EES technologies are considered as Carnot energy storage, since their operation occur with a theoretical round-trip efficiency of 100%. However, capital costs of such adiabatic concepts are still too high for an economical operation in future electricity transmission systems.

Large-scale conversion of electricity into thermal energy in a high-temperature heat pump cycle with subsequent conservation inside TES as indicated in Fig. 1 (right) increases the energy density of the overall process. Such process hybridization through the integration of Power-to-Heat (PtH) decreases the round-trip efficiency on the one hand, but, opens up the potential for improvements in flexibility as well as cost efficiency on the other hand. To this end, a Power-to-Heat unit has been developed at the German Aerospace Center based on a high-temperature PtH-concept, which comprises a pressure vessel (see Fig. 2) and an inductively heated and aerated rod bundle (see Fig. 3) to heat up the pressurized air to temperatures up to 600 °C.

Materials used for this process need to withstand high temperatures above 400 °C and pressures up to 12 bar at the same time. In addition, technology specific requirements due to the induction heating process must be met. These include high electrical conductivity and high permeability for Curie temperatures up to 700 °C. In order to meet these requirements a wide-ranged material investigation has been performed. Results from experimental studies illustrated in Fig. 4 show a significant slope of core temperature for iron-based materials, which reach temperatures above 700 °C with constant induction power of 2.0 kW. In contrast, the less efficient coupling of electromagnetic waves into Fe₃O₄ and graphite result in low temperatures.

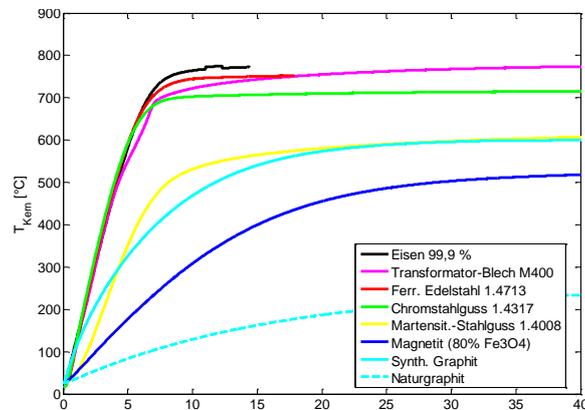


Fig.4: Experimental results for Curie temperatures of various inductively heated materials

The present contribution aims at introducing an experimental study for identification of well-suited material options for the induction heating process inside a solid media thermal energy storage. Based on an additional electro-thermal model [1], further results for energy- and cost-efficient material options for the application in compressed air energy storage will be presented.

Keywords: Compressed Air Energy Storage; Power-to-Heat; Induction heating; Curie temperature

Acknowledgements

Please acknowledge the funding authorities and other research supports.

Reference (Not more than 5, please follow the below reference style if any).

1. S. Belik, *Numerical modelling of an induction heating process for packed rods with adjacent airflow*. In: ELECTROTECHNOLOGIES FOR MATERIAL PROCESSING, p. 405-410. International Congress on Electrotechnologies for Material Processing, 06.-09. Jun. **2017**, Hannover.
2. V. Dreißigacker, Power-to-heat in adiabatic compressed air energy storage power plants for cost reduction and increased flexibility, *Heat and Mass Transfer*, 54.4, **2018**, 955-962.
3. Zunft, S., Dreißigacker, V., Bieber, M., Banach, A., Klabunde, C., & Warweg, O. (2017, November). Electricity storage with adiabatic compressed air energy storage: Results of the BMWi-project ADELE-ING. In International ETG Congress **2017**; Proceedings of (pp. 1-5). VDE.