The Reviewer's Comments on the PhD Thesis

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

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The Comments on the Thesis

The thesis focuses on the field of thermal energy storage technologies, specifically storage technologies in Carnot batteries.
The focus of the thesis is the research of thermal energy accumulation in basalt. The author deals with the research of selected relevant physical parameters of this substance, especially at high temperatures. This investigated temperature range is of great interest because it is then possible to directly use the gases in the mentioned Carnot battery technology.
In the paper, the tests of charging and discharging of the reference substance layer on a semi-operating unit in a fixed bed and in a stationary fluidized bed are also carried out and compared.
Thus, the obtained results on the given problem appear to be valuable. The topic is highly topical.

The main contributions of the thesis are as follows:

1. Experiments and mathematical model of the speed of reaching the full potential heat capacity of natural and cast basalt to describe natural and cast basalts charging and discharging behaviour for the use in packed bed thermal energy storage.
2. Evaluation of volumetric, density and surface changes of the natural and cast basalt due to the influence of cycling (charging and discharging, i.e. heating and cooling, of the material).
3. Comparison of packed and fluidized bed storage behaviour, based on experimental studies with sand, and proposal of multi-layered fluidized bed storage, offering specific temperature gradients according to the need of an application.

Processing, fulfilling the defined objectives of the work:

In the theoretical part of the thesis, the basic principles of Carnot batteries are described, a detailed overview of the current state of technology development is prepared, using examples of real units, i.e. demonstration, pilot units, which I evaluate very positively.

The substances used for thermal energy storage are presented, the need to work at high temperatures and the use of solids with appropriate physical properties and stability are justified.
The practical part of the work describes the tests carried out, experimental measurements to determine the heat capacity, heat content in selected samples, at different temperatures and residence times in the heated environment, i.e. in the charging process and in the cooling process, in the cooling chamber. The materials tested, the methods and the results obtained are, with some reservations, described in a clear and logical sequence. A standard empirical approach to data modelling has been used and I rate the methodology used here very positively.
In the practical part of the thesis, the tests performed on a semi-operational unit, i.e. in a stationary fluidized bed and a fixed bed, are further described. The results are presented in a clear manner, and the conclusions or interpretations could, in my opinion, be extended.
Specific criticisms, requests for clarification, additions are given in the "questions", but their nature does not, in my opinion, reduce the quality of the work itself.

It can be concluded that the defined objectives of the thesis have been fulfilled.

Formal and language level

The work is of a high quality and contains all the necessary formal requirements. The text and graphic part is structured logically and clearly.

Bibliography

The author works with 73 sources. These literature sources used seem to provide a comprehensive source of information on the relevant issue. The citations and their format given in the bibliography are adequate.

Novelty in results

The novelty of the work can be seen in the results of experimental analyses and their implementation in the mathematical model of the regenerative heating and cooling process, here specifically investigated basalt of certain composition and granulometry

Comments on the author's publications

The author's publications meet the requirements in terms of quantity set for doctoral programmes.

The Questions for the Defence:

Question 1:
The results shown in Figure 4.6, Figure 4.7, Figure 4.8 are referred to as the dependence of "heat capacity" and in Figure 4.15 as the dependence of "specific heat capacity" on time, i.e., the residency time of a given sample in the furnace at set temperature levels.
With respect to the results of cooling the samples, see Figure 4.11, where the stationary state was reached after a time of approximately 20 minutes. It can therefore be hypothesised that for the first samples taken from the furnace, the internal structure may still have been thermally inhomogeneous. This would also be suggested by the progression in Figure 4.10:

Then the appropriateness of using the term "specific heat capacity" is questionable.
It is clear that in non-stationary heat conduction, the geometry of the body is of importance among many parameters. The progression of heating of a sphere versus an elongated cylinder does not need to be elaborated.
Unfortunately, I do not find information about the sizes, basic geometrical features of the samples in the paper. Only ranges of masses are given. It can only be assumed that samples "similar" from this point of view were examined.
Query text:
Can it be assumed that the results obtained are therefore valid for a certain granulometric and geometric group, structure? Is it possible to generalise the results to other granulometries and particle geometries of the relevant substance?

Question 2:
The heating of the samples in the furnace was, I assume, under free convection conditions. There is no mention in the paper that the internal gaseous atmosphere was forced into motion. In real technology, however, the particle layer will be forced to flow through the gas, or convection will be implemented as forced as well.
Are the results of the change of the "heat content" in the samples over time, even taking into account possible non-stationary heat transfer, dependent among other parameters on the heat transfer coefficient? Do these differences need to be taken into account, and if so how?

Question 3:
On page 57, as part of the evaluation of the data obtained, is the sentence "At the same temperature (168.8◦C), the packed bed has a storage capacity of 7.65 kJ and the fluidized bed 3.04 kJ (40 % of the packed beds capacity)."
How is the storage capacity defined ?
(Shouldn't the energy stored in the same amount of the same material at the same temperature differential be the same?)

The Final Overview

The focus of the experimental work is the research of thermal energy accumulation in basalt, thermal capacity, especially at high temperatures, as well as conducting the actual tests of charging and discharging of the reference layer on a semi-operating unit in a solid bed and in a stationary fluidized bed, their comparison.
The progress of the work is systematic, logical, and adequate procedures and methodologies are chosen. The obtained data are carefully analyzed, evaluated. The author demonstrates independence and her expertise to an appropriate degree.

The results of the work are very beneficial with regard to their applicability in relevant real technologies.

Taking into account the professional quality of the work, demonstration of understanding of the topic, ability to apply scientific approaches and procedures in the experimental part, as well as in the part of processing and interpretation of the obtained data,

I recommend the work for defense.

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