Heat recovery from particles using a solid heat transfer medium

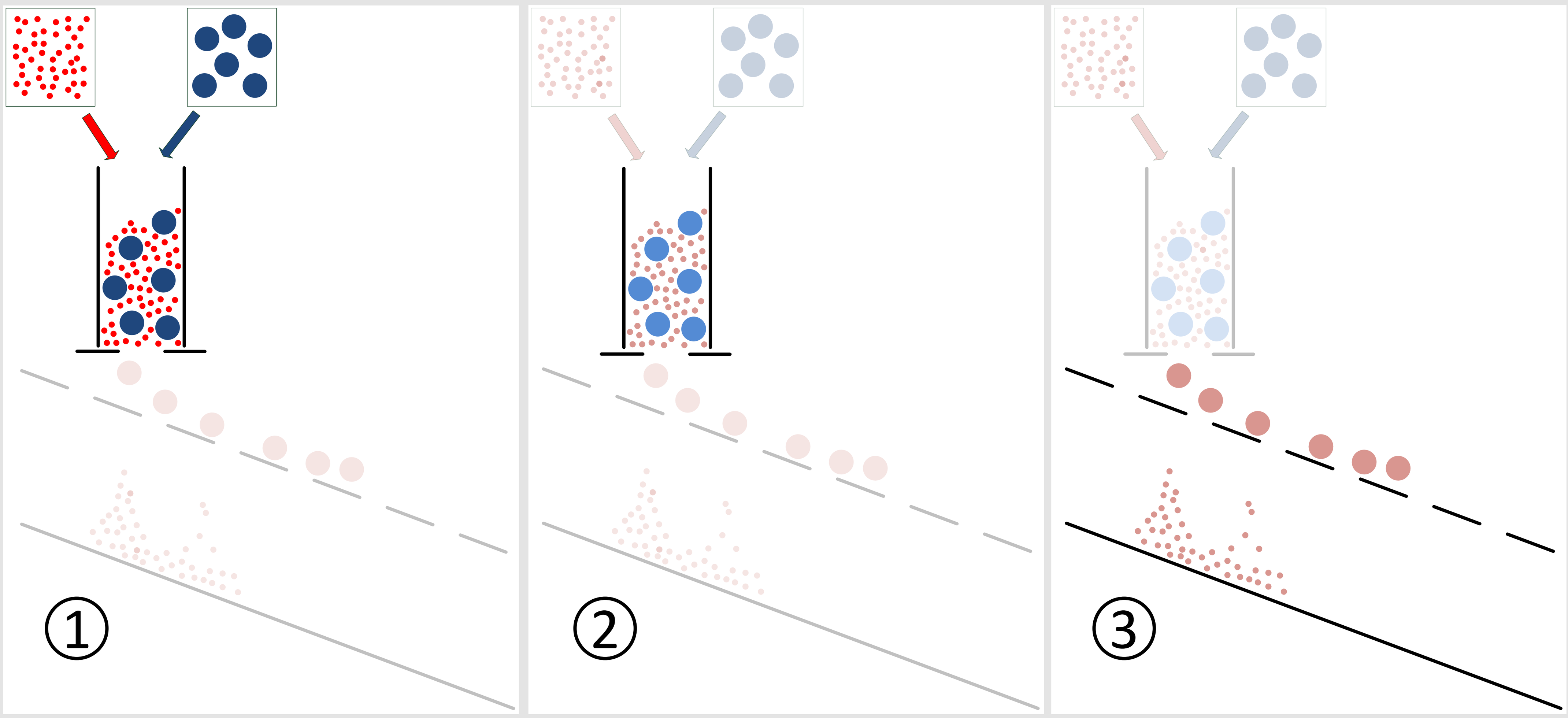

Figure 1 Procedure of the heat transfer: 1) Mixing of the redox particles and the heat transfer spheres, 2) heat transfer, and 3) separation.

Motivation

Solar thermochemical water splitting uses in a first step a redox material to produce hydrogen at a temperature of 1000°C, see Figure 2. In the second step, the redox material is regenerated with concentrated solar radiation in an endothermic reaction at 1400°C.

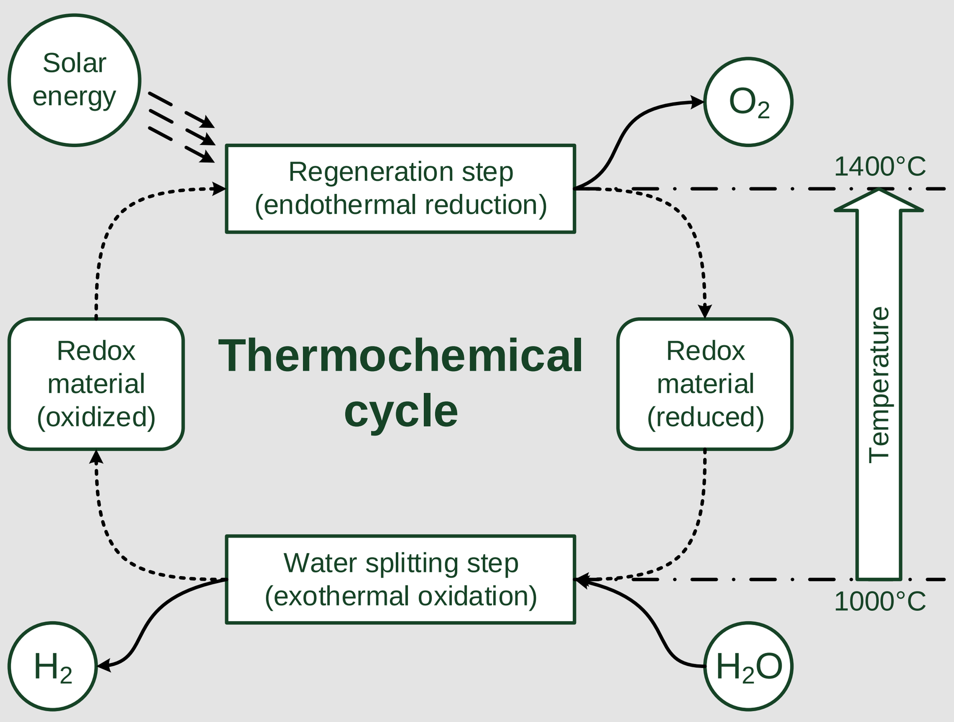

Figure 2 The solar thermochemical water splitting uses a redox material to produce hydrogen.

The major part of the solar energy (>80%) heats the redox material from 1000°C to 1400°C, which could be partly substituted by a heat recovery system.

Concept

The presented heat recovery concept bases on a spherical solid heat transfer medium. As Figure 1 shows, these spheres are mixed with the particulate redox material to transfer the heat directly. Afterwards, the spheres are separated from the redox particles.

Mixing the redox particles and heat transfer spheres results in a co-current heat transfer principle. The heat recovery rate of the system increases with the use of a quasi counter current principle, shown in Figure 3.

Performance model

A model was developed to calculate the performance of the concept. With a discretization of every stage, we take the non-linear assimilation of the temperatures into account. The heat transfer coefficient is calculated by assuming that the surface of the heat transfer spheres corresponds to an immersed wall in a packed bed of redox particles.

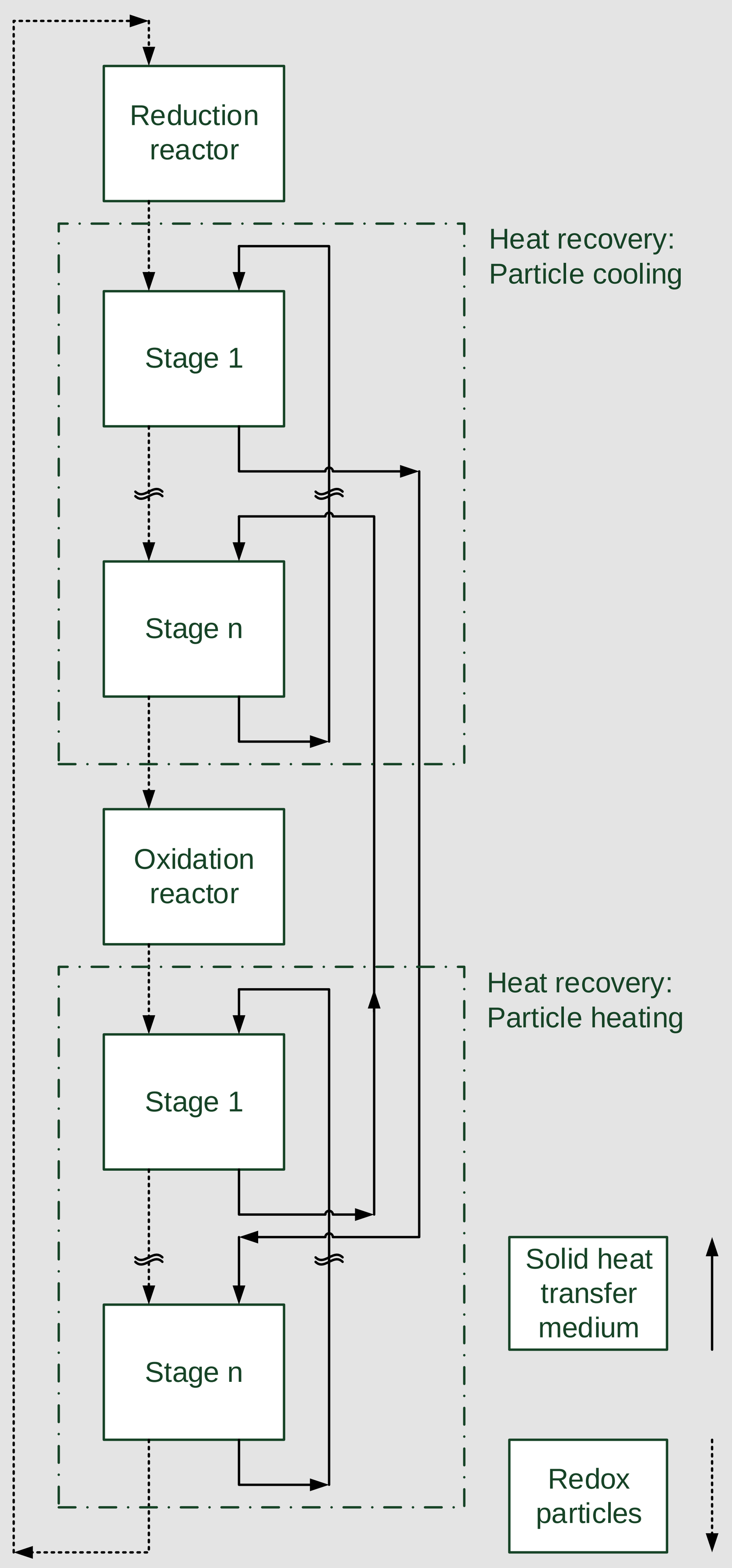

Figure 3 Scheme of the complete system that shows the flow of the redox particles and the heat transfer medium with a quasi counter current principle.

Material

The material we choose is

- 4mm alumina as heat transfer spheres
- 0,8mm ceria as redox particles

An analysis of the Biot number shows that it does not exceed values over 0.1 with the calculated heat transfer coefficient and the chosen diameter, hence we can use a perfectly stirred model.

Results

Analysed was the heat recovery rate, the quotient of the transferred heat and the sensible heat of redox particles between the two steps. It has been shown that the heat recovery rate depends on the molar flow ratio of the heat transfer spheres and the redox particles. The particular maximum occurs between a molar flow ratio of 0.7 and 1, dependent on the contact time, among 4s and 20s during each stage.

The contact time affects how much the temperature of the redox particles and the heat transfer spheres is assimilating to each other during the heat transfer process. Figure 4 shows that with a longer contact time the heat recovery rate moves closer to its maximum.

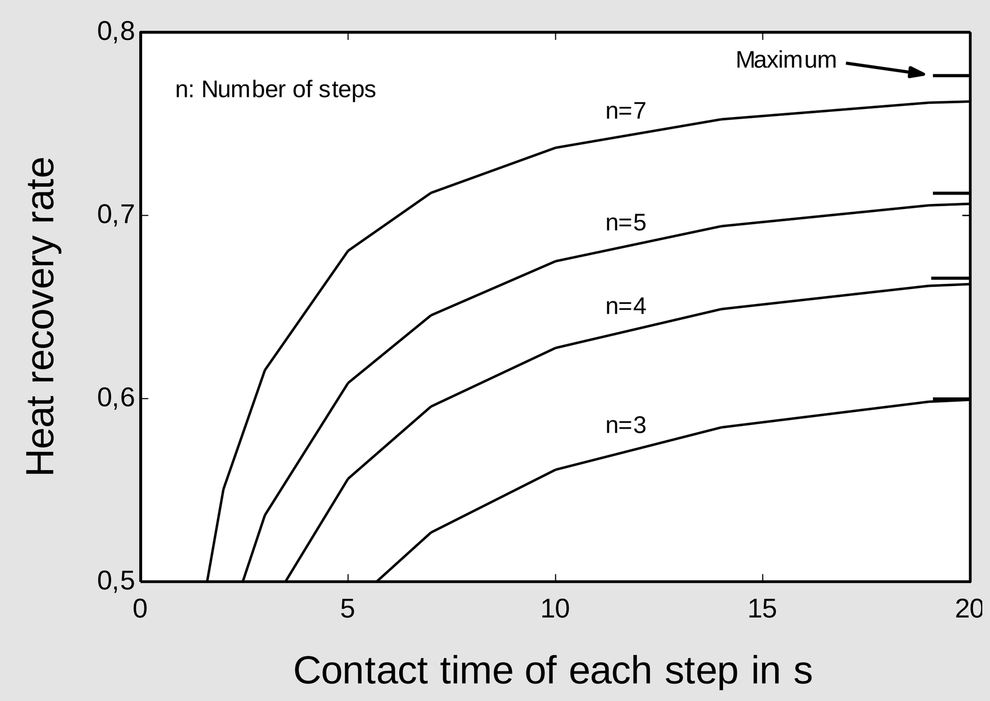

Figure 4 The development of the heat recovery rate to the maximum value depends on the contact time and the number of stages.

Discussion and Outlook

The presented heat recovery concept has the potential to improve the efficiency of the process significantly.

With an experiment, we want to measure the heat transfer coefficient that will certainly be down to the quality of the mixture, the contact time, the movement during the stage, and potentially other unknown parameters.

Jan Felinks, Stefan Brendelberger, Robert Pitz-Paal
Institute of Solar Research, German Aerospace Center (DLR)
Jan.Felinks@dlr.de, 02203 601-4069

DLR Deutsches Zentrum für Luft- und Raumfahrt

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