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SOLPART

High Temperature Solar-Heated Reactors for Industrial Production of Reactive Particulates

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Deliverable 2.3

WP2 – Lab scale development and testing of 800 – 1000 °C solar reactors

Deliverable 2.3. Report on experimental results obtained with the lab-scale solar reactors

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1. Introduction

This report presents the main results obtained during the test campaigns of the laboratory-scale solar reactors at CNRS and DLR.

CNRS has developed the vertical and horizontal fluidized bed reactor design and DLR the rotary kiln design. As a result, three prototypes have been tested.

At CNRS, the experiments have been carried out with the 1 MW solar furnace using a part of the heliostat field and off-focus configurations. At DLR, main part of the experiments have been made with a solar simulator. In both cases, incident power was in the range 10-20 kW.

Concerning the particles, both laboratories performed a first set of experiments with inert particles. Then, CNRS focused effort on dolomite calcination whereas DLR studied cement raw meal (CRM) calcination. Reactive particle inlet mass flow rate was ranging from 5 to 15 kg/h.

It is important to note that the mean particle size and the particle size distribution have a strong importance on the particle flowability and, consequently, mixing ability inside the reactor. This property affects drastically the reactor performance.

A critical analysis of the experimental results is proposed in WP2.4.

2. Conclusion

Three experimental campaigns were performed to evaluate the solar rotary kiln as a reactor for the treatment of reactive particulates. The first campaign was focussed on the thermal performance and the treatment of inert particles. Taking unsteady operations also into consideration, efficiencies between 27 and 45 % were achieved (see Figure 49, left). With a power input of 13.2 kW, material flows of Bauxite in the range of 8.7 – 16.9 kg/h were heated up to 1000 °C.

After gaining the first experiences in the operation of the rotary kiln and improving the insulation of it, the second campaign was performed. This time in steady operation an efficiency of 54 % was achieved. Results of unsteady operation hinted at an efficiency of about 62 % with a material flow of 28.7 kg/h of Bauxite leaving the kiln at 960 °C (see Figure 49, middle). Furthermore, for the first time two chemical runs were performed. During the first run on 19.04.2017 5.9 kg/h of cement raw meal was calcined to a degree of over 90 %. Although this would be close to the requirements for further processing of the product, continuous operation was not possible with this closed configuration. The injection of pressurized air at the window was later found to be the main cause for this. Increasing the gas flow worsened the deposition on the window which is why the second run in this campaign did not provide any data for analysis.

Before going into the third and final campaign a different approach for avoiding window deposition was taken. Applying suction from the back of the reactor proved to be efficient to avoid particle deposition in cold state and was realized for the hot tests. Again, first the thermal performance of this configuration was analysed (see Figure 49, right). 28.7 kg/h of Bauxite particles were continuously heated to 1060 °C with an efficiency of 62 %. The window did not show any major deposition or degradation after this operation. After changing the feeding material to the cement raw meal multiple difficulties for the operation arose. First, the feeding of the material for a longer period was not possible because of its fine size and high humidity. Second, the suction system, which utilized 4 pipes with a diameter of 10 mm, was clogged due to the dust severity and the condensation of water inside the pipes. Due to this the window could not be maintained free from deposition and no operation was possible. After switching to the open configuration without a window and replacing the cement raw meal with coarser and dryer samples continuous runs could be performed. The suction for the open operation was applied at two points, of which one was inside the kiln to remove most of the evolving gas and the dust. The other suction point was at the front flange to avoid the contamination of the simulator room. During the run on 16.10.2017 11.4 kg/h of cement raw meal were treated for over 1.5 hours with a total efficiency of about 37 %. The material was calcined in average to a degree of 45 % resulting in a chemical efficiency of 15 %. The run on the next day was operated with an increased mass flow and provided slightly better results. No steady operation was achieved in that case since the feeder stopped for some moments. The last run on 20.10.2017 was performed with a lower material flow of 7.4 kg/h. Keeping all other parameters like input power and rotational speed the same as before, much better calcination of above 95 % could be shown. Due to the clogging of the hopper again no steady operation could be reached.

In summary, the continuous operation of the solar rotary kiln with cohesive and reactive particulates was shown in an open configuration. Conversion rates of the product were relatively low in this configuration. One possible reason for this can be the low temperatures in the kiln caused by the application of a controlled suction to avoid particles leaving the reactor. Due to these temperatures either the calcination was not happening fast enough or a reconversion of the material happened in the front, cooler part of the reactor. Another factor can be the relatively high mass flow of material which may have required a change in rotational speed and inclination to maintain a good mixing of the bed. Reducing the mass flow resulted in much better calcination rates but showed other issues like clogging. In the end the solar rotary kiln showed promising results while more experiments would be needed to reach a reliable operation with a high degree of calcination.

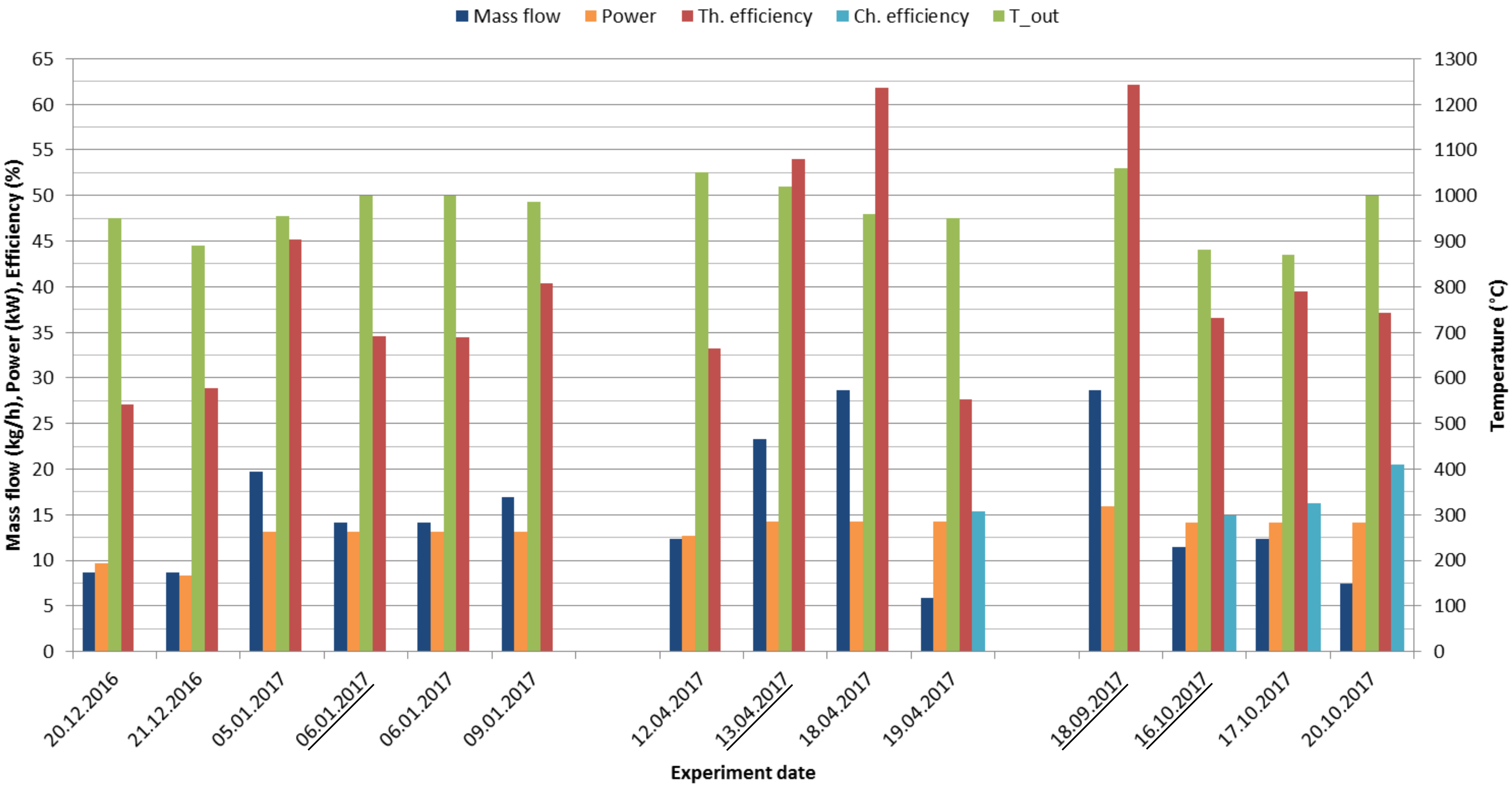

Figure 49: Comparison of the first (left), second (middle) and third (right) experimental campaign. The date of runs with steady-state is underlined.

3. References

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