PYROLYSIS OF WASTE TO SYNTHETIC FUELS ON CEMENT PLANTS

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1. Highlights

- 60 wt.% oil yield was obtained from a fluid bed model reactor pyrolysis operation with biomass.
- Fluid bed pyrolysis experiments with Geldart C-type of particles demonstrated promising results.
- 50 wt.% oil yield was produced from cement raw meal pyrolysis with an average of 30% water content.
- Experiments are recently being conducted with the focus on real waste feeding.

2. Purpose

The demand for cement has continuously been rising due to growing populations and urbanization. According to the International Energy Agency (IEA), the cement industry generated around 2.9 billion tons of CO2 in 2021 [1], thus accounting for 8% of global anthropogenic CO2 emissions. The sector is thus facing significant expansion at a time when its emissions need to fall fast. From a technical perspective, there are a number of solutions for reducing the emissions associated with cement production. The use of alternative fuels and raw materials for cement clinker production is of major importance. In Europe, the cement industry has already replaced a part of its traditional fuel sources with waste or biomass, which leads to a reduction of CO2 emissions [2]. The possibilities to integrate a pyrolysis-based liquid fuel production into a cement plant are investigated in this work. The process will use CRM (CRM) from the plant pre-heating tower as a heating source for the pyrolysis process. The pyrolysis products could be applied as fuel to the kiln burner or as a liquid fuel to be provided to external customers. A particular challenge is that CRM is difficult to fluidize, and that waste fuels show large variations, as it is desired to apply different waste types and biomass.

3. Materials and methods

In this study, a recently constructed laboratory fluid bed pyrolysis reactor that can simulate the conditions in a cement plant system was applied for experiments with different fuel types. The experiments include changes in reactor residence time with different tested fluid bed materials and outline of product collection system. Further development and optimization of the system is being done aiming to optimize the liquid yield and quality, and future experiments will include studies on the influence of using different waste fuel types. The experimental work was initiated with the study of beech wood with sand as an inert bed material and followed up with the CRM as an intended material from the cement process.

The pyrolysis experiments were performed on the fluid bed pyrolysis reactor with constant operating conditions: a pyrolysis temperature of 500 °C to fully decompose the biomass, a gas residence time of 4 – 5 seconds to ensure limited cracking reactions of the tar compounds, a minimum feeding rate of 0.17 kg/h and a comparable total feed consumption range of 300 – 500 g biomass for each run. Nitrogen as a carrier gas was injected into the system from different ports at a total flowrate of 17 Nl/min to maintain a desired gas residence time in the reactor. In addition, both quartz sand and CRM (700 g in each experiment) were used as bed material in the experiments, having a particle diameter lower than 350 µm and 100 µm, respectively. In the CRM experiments, fluidization was obtained by the exertion of a nitrogen pulsation. Nitrogen pulsed flow parameters were optimized by the study of CRM in a cold model fluid bed reactor which has an identical design. Before the pyrolysis experiment, the feed and bed material were pre-dried overnight at 105 °C and 60 °C, respectively. The experiments using beech wood proceeded smoothly and proceeded for more than an hour of fuel feeding time.

Liquid, gas, and solid products from different parts of the downstream product collection system were individually analysed in order to achieve product balances for each experiment.

4. Results and discussion

Two sets of fast pyrolysis experiments were carried out on the laboratory scale fluid bed reactor by using beech wood: quartz sand (< 350 µm) and CRM (< 100 µm) as bed materials.

Details of quartz sand-based experiments were listed in Table 1 which shows promising and repeatable results. In terms of produced liquid yield, more than 60 wt.% on a dry basis has been achieved with similar gas yields being around 30 wt.% and a slight difference in the solid yield. While mass balances were established for both experiments, the average water content in the produced liquid products demonstrated identical values. Moreover, the residence times were very similar to each other due to similar gas yields.

Table 1. Detailed results from beech wood pyrolysis experiments with quartz sand

Parameter	**Experiment A**	**Experiment B**
Bed material (dry)	Quartz sand	Quartz sand
Total fed weight (g) (dry)	310	465
Yield (wt.%)	Liquid: 60 Solid: 17 Gas: 28	Liquid: 63 Solid: 11 Gas: 30
Mass balance closure (wt.%)	105	103
Carbon balance closure (wt.%)	100	100
Average water content (%)	34	32
Residence time (sec)	4.67	4.64

In the CRM experiments, pyrolysis operational conditions were kept the same with an additional pulse flow by a pulse generator. Pulsed nitrogen flow was given from the bottom of the reactor at a 1.5 Nl/min flowrate and 50 mS open/500 mS close pulsation times. Two runs of CRM pyrolysis experiments with beech wood showed more than 50 wt.% liquid yield with a promising repeatability in regard to products yield, CO, CH_4 and CO_2 gas signals, and mass balance closures.

Experiments are recently being conducted with the focus on real waste feeding.

5. Conclusions and perspectives

In the present study, pyrolysis product distributions are an important criterion to systematically identify the correlations between adjusted operational conditions and their corresponding product yields. By pre-drying the feed material and shortening the residence time spent in the reactor at pyrolysis temperature of 500 °C, the liquid product yield was increased from 40 wt.% to 63 wt.% and average water content in the produced liquid yield was decreased from 60% to 32%. CRM experiments demonstrated promising results with more than 50 wt.% pyrolysis oil yield when it is compared to the Geldart C-type of particles study in the literature. Research is ongoing with the use of different feed materials such as plastics and refused derived fuel (RDF) to establish the most efficient operation conditions for a cement plant-based pyrolysis oil system.

References

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