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# Agglomeration and Deposition Behaviour of Solid Recovered Fuel

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## 1. Introduction

Waste derived fuels such as Solid Recovered Fuel (SRF) are increasingly being used in the cement industry as a means to reduce cost [1]. SRF is produced by separating the combustible fraction from industrial or municipal solid waste (MSW). The recovered fraction has a higher content of combustible materials such as plastic and paper than mixed MSW [2]. The inhomogeneous nature of SRF [3] makes it difficult to combust and many problems may arise concerning e.g. combustion control, feeding of fuel [2,4], deposit formation [5], or accumulation of impurities [3].

Laboratory ash fusion tests typically show that SRF ash starts melting in the range of 1150-1200 °C [6–8], which is somewhat lower than most coal ashes. However, experiments performed in fluidized bed has shown agglomeration taking place as low as 970-990 °C [9,10], and the predictability by ash fusion tests is generally poor [10].

SRF contains significant quantities of common plastics such as polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET). Fluidized bed experiments to examine the pyrolysis of polymers have shown that bed agglomeration can result from melting plastics or sticky char residues in the case of PET [11,12].

The main objective of this study was to characterize the combustion of SRF and especially the deposition propensity of SRF and the main constituents of SRF. This relates both to the low temperature deposits formed during plastic pyrolysis and the high temperature deposits formed by ash. The issues reported in the literature regarding plastic pyrolysis will here be investigated at temperatures above 800 °C that are more common in combustion. It will also be attempted to determine if SRF ash may cause issues below 1000 °C, as indicated by some literature results.

## 2. Method

The combustion of polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), pinewood, and SRF were studied in an electrically heated rotary drum furnace (see Fig. 1). This rotary drum has been constructed to simulate the conditions at the material inlet of a cement rotary kiln [13,14]. The setup has been slightly modified for use in this study by fitting a smaller drum (150 mm diameter, 150 mm length) inside the existing one. The

improved viewing angle of the smaller drum made it easier to observe the combustion process inside the furnace. An extra window was installed for a powerful flashlight.
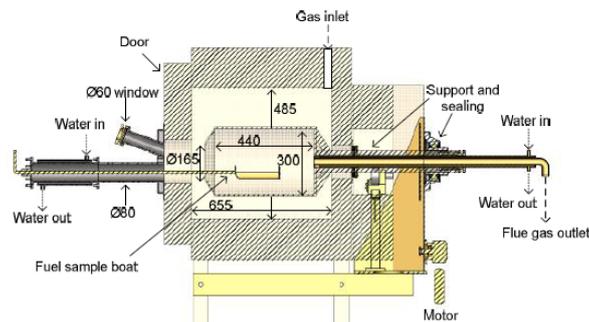


*Figure 1. Rotary drum furnace setup. For use in this experiment, a smaller drum (150 mm diameter, 150 mm length) was fitted inside the existing drum.*

The combustion was carried out at temperatures of 800, 900, and 1000 °C, with an oxygen concentration of 10 %, achieved by mixing nitrogen with atmospheric air (total flow 100 Nl/min). The drum speed was 6 revolutions per minute. The sample quantity was in the range 0.2-0.3 g per experiment. As it was impractical to empty the drum before introducing another sample, the drum was cooled and cleaned after approx. 20 samples. The combustion process was recorded by a high-speed camera (60 frames per second).

It is believed that the direct visual observation of the combustion behavior and deposition propensity of different fuels is valuable in comparison with indirect methods. The results are applicable for SRF combustion in e.g. fluidized beds or non-slagging cyclone furnaces [15], although the experimental setup is designed differently.

## 3. Results

### 3.2 Polyethylene (PE) and Polypropylene (PP)

PE and PP are completely volatile [16] plastics forming no char. The plastics behaved very similarly. They melted quickly after being injected; forming droplets that moved around at the bottom of the drum (see Fig. 2, left) and evaporated in a few seconds

### 3.3. Polyethylene Terephthalate (PET)

PET typically has a fixed carbon content of 5-10 wt% [16] and it behaved significantly different than PE and PP. Almost immediately after the injection the PET pellets stuck to the drum wall (see Fig. 2, right), where they stayed during the devolatilization and char combustion. At 800 °C, the pellet residue detached shortly after the char combustion had ended, but at higher temperatures it stayed attached to the wall. The PET pellets used in this study contained 30 wt% of glass [17], and this residue is likely the source of deposits at 900 °C and above. The amount of glass in SRF may be as high as 3 wt% (depending on the quality) [18] and glass melting starting at 850 °C has been reported as a problem in fluidized bed combustion of SRF [19].

### 3.4. Pinewood

No problems regarding deposition were observed using pinewood chips. It was observed that the smallest char and ash particles could adhere lightly to the drum wall, but they detached by light knocking on the drum.

By blending samples of wood and polymer (approx. 1:1 ratio) it was observed that the wood could attach to molten polymer. A large agglomerate was formed, as shown in Fig. 3 left, in a case where pre-molten PE was mixed with wood and then injected into the drum. The agglomerate disintegrated after the devolatilization of the polymer. Wood particles were also able to adhere to the PET pellets stuck to the wall.

### 3.5 Solid Recovered Fuel (SRF)

SRF had low tendency to stick to the wall of the drum. Typically only 5-10 % of the injected SRF stuck to the wall for more than one revolution of the drum (10 seconds) (see Fig. 3, right). This could possibly be caused by PET, or other char forming plastics in the SRF. The majority of the SRF slides to the bottom of the drum, where it forms agglomerates, much like the blend of wood end PE. The remaining ash particles did not melt even at 1000 °C, although the smallest particles could adhere loosely to the drum wall.

## Conclusions

PET and SRF may form deposits in a combustion environment due to sticky char particles. The deposits may be managed by securing proper combustion of the sticky char constituents, since the particles eventually detached from the wall during the char oxidation phase. The fully volatile plastics PE and PP rapidly devolatilize when in contact with a hot surface and are not prone to form deposits. However, the molten polymer may stick to other cold fuel particles and cause fuel agglomeration, which potentially increases the conversion time.

The ash from SRF or pinewood was not found to pose a significant risk of melting and deposit formation at temperatures below 1000 °C, however the presence of glass impurities may increase the risk significantly.
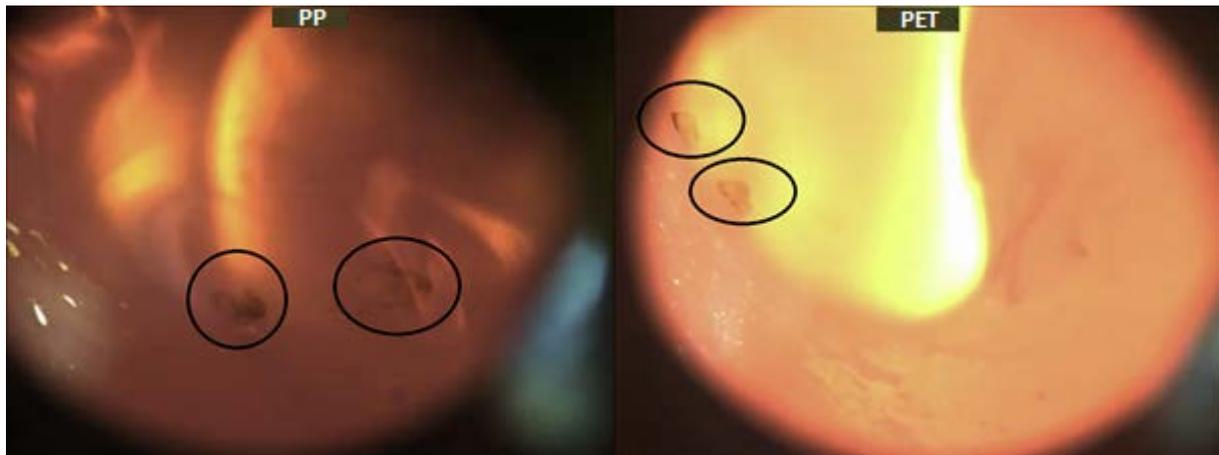
*Figure 2. Left: Combustion of PP (0.2 g) at 800 °C. A melt is formed, which flows to the bottom of the drum without sticking to the wall. Right: Combustion of PET (0.2 g) at 800 °C. Pellets stick to the drum wall*
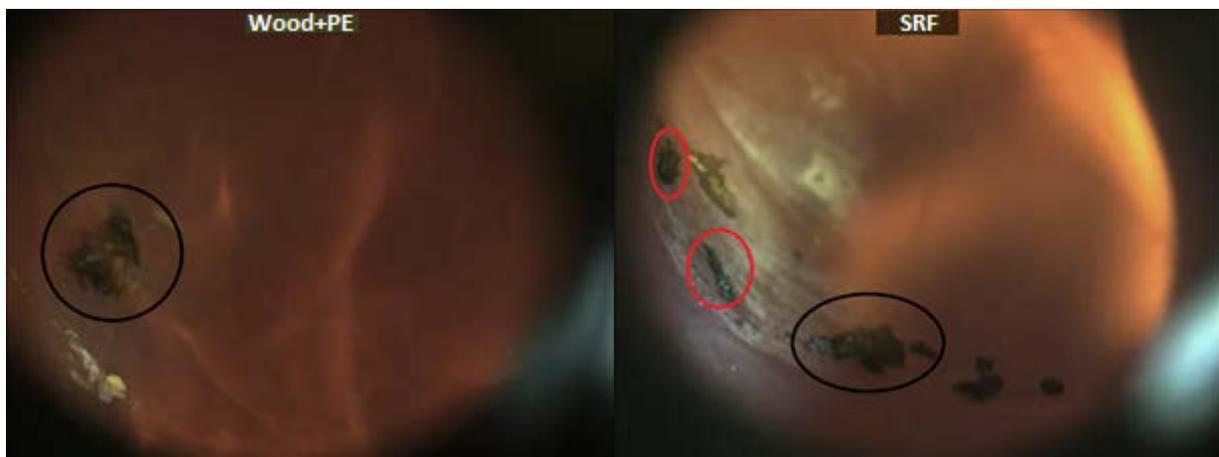


*Figure 3.Left: Combustion of blend of PE (0.2 g) and pinewood chips (0.3g) at 800 °C. A large agglomerate is formed, which falls apart after devolatilization of the plastic. Right: Combustion of SRF (0.3 g) at 800 °C. Particles marked by black have formed an agglomerate and particles marked by red stick to the wall.*

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