

THERMO-CHEMICAL RECYCLING OF AUTOMOBILE SHREDDER RESIDUE IN DFB GASIFIER

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Abstract

Automobile Shredder Residue (ASR) is the fraction left after metal recycling of cars, and it is composed by a plastic mix with up to 50% of inorganics. The gasification of ASR was studied in the 2-4 MW_{th} Chalmers Dual Fluidized Bed (DFB), aiming to convert this diverse fraction into valuable products. Ash-rich fuel, such as ASR, make the bed rapidly be composed of ash. Thus, aiming to reduce process costs, two beds were evaluated: ASR-ash as bed and a steel production by-product, LDslag. Results showed that enrichment of the initial olivine bed with ARS-ash lead to the decrease of Carbon recovery, while the oxygen transport ability of the Iron present in LDslag enhanced the conversion but producing more CO₂ yields. Both bed materials are viable options to valorise waste via DFB gasification, reducing the need of the addition of fresh bed.

Keywords: *Automobile shredder residue, fluidized bed gasification, plastic waste, thermo-chemical recycling*

1. Introduction

Global population expansion and economic development of the society has headed to increasing consumption of resources already exploited. Hence, waste management has become a growing concern, leading to efforts to recycle more complex waste streams. One example is car recycling, according to the EU Directive 2005/64/EC, 85% of the vehicle weight should be recycled. However, just 75%_w is scrap metal that is currently recycled [1,2]. Once when car goes through mechanical recycling, the fraction rich in plastic, called Automobile Shredder Residue (ASR), is left. This fraction is a highly non-homogenous stream containing a mixture of plastics and foams (i.e. PUR, PMMA, ABS, PP, PET, PVC) together with up to 50% of inorganics, such as fillers, metals and glass. The diverse composition complicates further recycling; thus, disposal or combustion are commonly applied [2].

This works investigates the thermal conversion of ASR into valuable products such as syngas and hydrocarbons, in the Chalmers gasifier. Dual Fluidized Bed (DFB) gasification with olivine as bed has been researched and its activation showed beneficial effect on the product gas [3]. However, gasification of fuel rich in ash will

diminish the benefits of using olivine, as the bed will rapidly be composed of mainly ash. Consequently, regular regeneration of bed will be necessary, increasing the process expenses. The possibility to run the process with ASR-ash enriched bed material was studied. Additionally, the process has been tested with low cost material, a rest fraction from steelmaking as a bed material, LDslag, iron rich material, where the drive was the possibility to simultaneously valorise two waste streams.

2. Materials and Methods

The experiments were performed in the Chalmers Research Gasification Unit, which is composed of a 10-12MW_{th} circulated fluidized bed boiler and 2-4MW_{th} bubbling bed gasifier, fluidized with steam [4]. The process was evaluated through the characterisation of the raw gas produced in the gasifier, where two gas streams were taken: (i) to determine the permanent gas composition and the aromatic hydrocarbon content; and (ii) to establish a carbon balance over the gasifier. Helium has been added to the process as a trace gas. The concentrations of the main constituents of the produced gas: H₂, CO, CO₂, CH₄, and light hydrocarbons (C₂- and C₃-species) were measured on-line using *microGC*. The aromatic fraction was sampled using the Solid Phase Adsorption [5]. The carbon balance was closed by use of the High-Temperature Reactor as described by Israelsson et. al. [6].

Table 1 shows the gasifier operating conditions. As ash- rich fuels lead to large exchange of the bed, the following beds are compared at 790°C: (I) ash-free olivine; (II) 80% of ASR-ash accumulated in olivine bed; (III) blend of 15% silica sand and 85% LDslag. Additionally, as temperature has significant influence, cases (II) and (III) were also examined at 820°C. The ASR composition slightly changed during the campaign, which was, on dry mass basis, 46%Ash, 33%C, 4%H and 14%O for (I) and (III), and 32%Ash, 47%C, 5%H and 13%O for (II).

Table 1. Operational points of ASR gasification

	Bed material (circulation tn/h)	Temp. gasifier (°C)	Steam flow (kg/h)	Fuel flow (kg _{dat} /h)
I	Olivine (n.a.)	794	161	189
II-a	80%ASR-ash (18)	792	160	173
II-b	80%ASR-ash (19)	824	160	172
III-a	85%LDslag (30)	790	161	195
III-b	85%LDslag (30)	820	161	196

3. Results and discussion

The carbon in the product is distributed between five fractions: gas (CO, CO₂, CH₄, C₂- and C₃-hydrocarbons), SPA tar (measured aromatics), non-identified (aliphatic from C₃+higher and unidentified aromatics) and uncovered fraction. *Figure 1* shows the Carbon recovery of those fractions in mol per mol of C_{dry ash free fuel} for evaluated cases.

The percentage of carbon recovered in form of permanent gas was similar, around 60%, for both ash-free olivine (I) and for LDslag (III-a), at 790°C, whereas for ash-rich olivine (II-a) was significantly lower, 41%. The carbon content in the aromatic fraction was not visibly affected by the selection of the bed or ash presence and showed to be similar for all cases. The total carbon conversion (calculated as: $C_{\text{total conversion}} = C_{\text{Gas}} + C_{\text{SPA}} + C_{\text{non-identified}}$) was the lowest, 67%, in case of olivine bed enriched with ash (II-a), while 80% was converted for ash-free olivine. For the LDslag tests, it was not possible to calculate non-converted fraction and consequently non-identified fraction, but even from gas and SPA results it can be concluded that the conversion is over 70%, which is higher than for the ash-rich olivine bed.

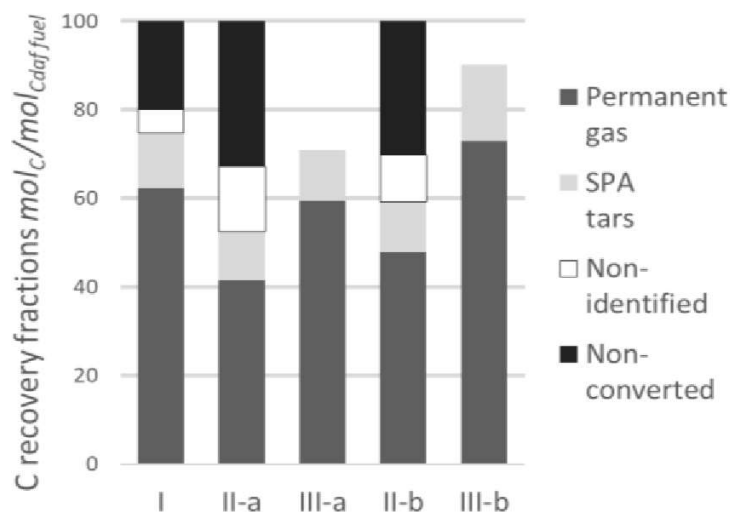


Figure 1. Carbon recovery (molC/molC_{daf fuel})

Ash-free olivine (I), ash-rich (II), LDslag (III) at 790°C (a) and 820°C (b)

Higher temperature shows to be beneficial for obtaining a higher gas yield for both (II-b) and (III-b). Again, LDslag produces substantially higher gas yields and total conversion than ash-rich olivine, the last one being over 90% for (III-b) compare to a 70% for (II-b). *Figure 2* presents the yield distribution of permanent gas. At 790°C, ash-free olivine seems to favour the formation of H₂ and light hydrocarbons (CH₄, C₂-C₃), whereas ash-rich bed and LDslag obtain lower yields of those species. When increasing the temperature to 820°C, CO₂, H₂, C₂-C₃ and tars increase in both cases (II-b, III-b), in contrast to CH₄ that slightly decreases. Comparing ash-rich bed (II) and LDslag (III), it can be observed that the carbon conversion of (III) is considerably higher than for (II). This is likely due to both a higher circulation for case (III) and higher oxygen transport, leading to increased conversion into CO₂, whose concentration is 55-65% of the permanent gas. In contrast, CO₂ concentration for ash rich olivine is 40% of the gas produced, while it produces more syngas than LDslag.

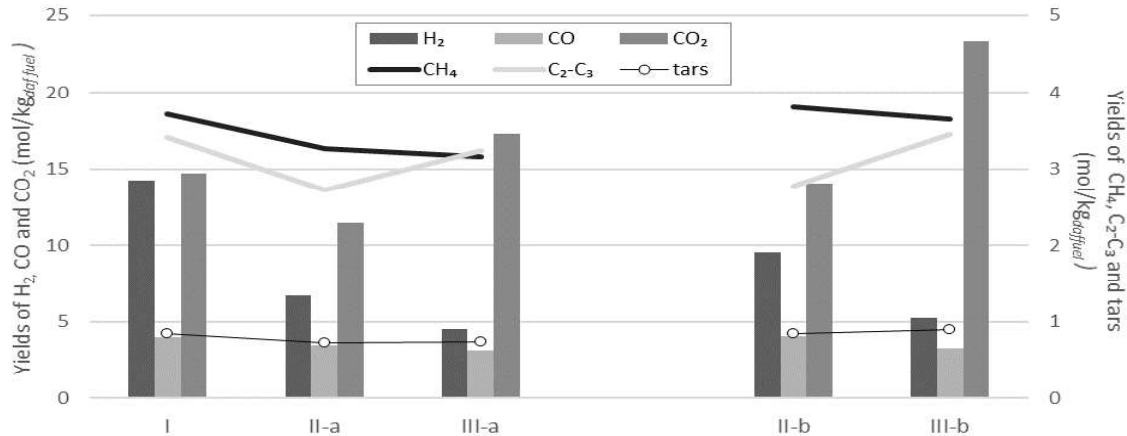


Figure 2. Gas yields distribution: ash-free olivine (I), ash-rich (II), LDslag (III) at 790°C (a) and 820°C (b).

In summary, LDslag achieved better Carbon conversion, at the expense of more CO₂ yields, which may not be beneficial if the aim is chemical recovery. Both II and III produced similar C₂-C₃ yields, around 3 mol_C/kg_{daff}, which could be used as a feedstock in petrochemical industries. Finally, ASR-ash rich bed obtained valuable syngas, and, although the total gas yield was lower, the unconverted fuel could be use as heat for the gasification process.

4. Conclusions

LDslag and ASR-ash enriched olivine are viable options to valorise waste as a bed material for DFB gasification, reducing bed regeneration requirements. LDslag showed higher conversion but produced less gases to use as a feedstock, in comparison to ASR-ash enriched bed. In conclusion, both options seem attractive alternatives for sustainable waste management.

5. References

- [1] Buekens, A.; Zhou, X. *Journal of Materials Cycles and Waste Management* 2014. 16(3), 398-414.
- [2] Maric, J.; Berdugo, T.; H. Thunman; M. Gyllenhammar; M. Seemann. *Energy & Fuels* 2018 32 (12), 12795-12804
- [3] Maric, J.; H. Thunman; Knutsson, P.; M. Seemann. *Chemical Engineering Journal* 279, 2015, 555-566.
- [4] Larsson, A.; M. Seemann; D. Neves; H. Thunman. *Energy & Fuels* 2013. 27(11): p. 6665-6680.
- [5] Israelsson, M.; M. Seemann; H. Thunman. *Energy & Fuels*, 2013. 27(12): p. 7569–7578.
- [6] Israelsson, M.; A. Larsson; and H. Thunman. *Energy & Fuels*, 2014. 28(9): p. 5892-5901.