

Two stage pyrolysis/split product gasification of refused-derived fuel (RDF)

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Refuse-Derived Fuel (RDF) is produced from MSW by separation of incombustibles and biologically degradable fractions. Main components of RDF are paper, cardboard, plastic, textile, and wood. Approximately 40 % of the original mass of MSW corresponds to RDF [1]. Removal of components with low heating value and additional drying lead to an increase of lower heating value of RDF up to 23.7 MJ/kg [2]. Gasification has a great potential to convert RDF to useful chemicals and energy as it produces combustible gases consisting mainly of H₂, CO and CO₂. However, the gaseous product also contains small amounts of solid particles, light hydrocarbons, tar, and traces of H₂S, NH₃, and HCl [3]. Tar condensation causes fouling and corrosion of downstream processing units and tar has to be removed from the product gas. Although much attention has been devoted to gasification in recent years, there are still many challenges to overcome before full commercialization of MSW gasification. Heterogeneity of raw materials, gas tar content, and reduced efficiency are the main technical challenges.

In this study, a gasification unit consisting of a pyrolysis stage and a separate product (solid phase and volatile phase) gasification stage (PSPG) was investigated considering increase of gas lower heating value (LHV), reduction of gas tar content (GTC), increase of cold gas efficiency (CGE) and carbon conversion efficiency (CCE). RDF samples were subjected to experimental study. Gas composition and tar content of gas were observed under different process conditions.

RDF obtained from a waste recycling company in Slovakia was ground and pelletized to pellets of 5 mm diameter and 8 mm height. It was characterized by thermogravimetric analysis (TG), elemental analysis (EA), calorimetric analysis (CA), and differential scanning calorimetry (DSC). Samples for RDF characterization were homogenized by grounding of around 500 g of pellets to powder. All measurements of RDF characterization were done at least in triplicate to obtain average values with relative deviation below 10%.

A char-based catalyst was used for tar cracking in the secondary volatile gasification stage. Composition of the catalyst was estimated by a CHNOS analyser. Microstructure of the prepared catalyst was characterized using a surfer gas adsorption porosimeter. Standard BET adsorption isotherm procedure was used to calculate the catalyst's specific surface area.

Figure 1 shows the experimental apparatus used in this work. The main components of the apparatus include a pyrolysis reactor (PR), secondary catalytic reactor (SCR), and a char gasifying reactor (CHGR). Feedstock is fed to PR by a feeding screw. Nitrogen is fed to the hopper to prevent backflow of gases from PR. Outlet of PR is connected to a separating chamber where pyrolysis coke is separated from pyrolysis gas. Pyrolysis coke is led from PR to CHGR. Air required for pyrolysis coke gasification is fed from the bottom of the CHGR. Produced gas leaving CHGR is led to a mixing chamber where it is combined with pyrolysis gas from PR and additional air. The gas mixture enters SCR filled with the catalyst. Gas leaving SCR is cooled and after samples for gas composition measurement are taken, it is combusted in a combustion reactor. Gas composition was measured by a gas chromatograph with both a flame ionisation detector (FID), and a thermal conductivity detector (TCD). Temperature in PR was set to 600 °C while in the gasification reactors it varied between 700 °C and 900 °C.

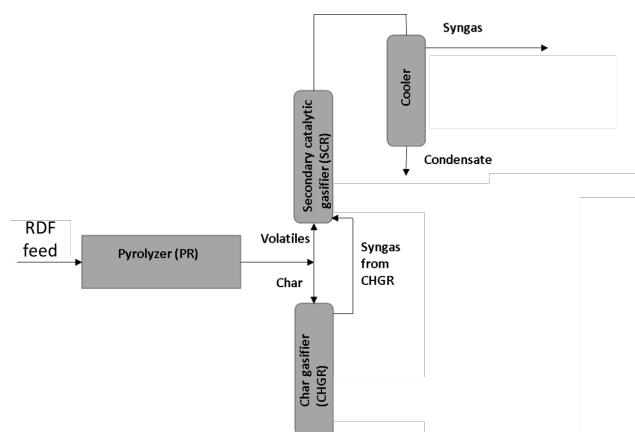


Figure 1: Scheme of two stage pyrolysis/split product gasification process

Preliminary gasification experiments have shown that splitting of oxidising agent between a char gasification reactor and a secondary catalytic reactor is of great importance as the air split ratio (ASR) between secondary catalytic and char gasifying reactors has a significant effect on the RDF gasification system performance. Tar content in syngas is significantly affected by the air split ratio; splitting air between secondary catalytic reactor and char gasification reactor reduces the tar content in syngas. Increased air flow in the secondary catalytic reactor leads to the reduction of coke formation inside the reactor. Also, equivalent ratio (ER) has a significant effect on gas composition and LHV/GTC ratio. Optimum ER, at maximum LHV/GTC in dependence on C/H ratio of feed, was between 0.25 and 0.35. Catalytic effect of char-based catalysts has been confirmed. The presence of a catalyst in SCR reduces the gas tar content by more than 70%. In future work, more experiments with different catalyst loading and larger regions of ASR and ER will be done to determine global optimal conditions for achieving lowest gas tar content, highest LHV, highest CCE, and highest CGE.

References:

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