Hydrogen Production from Wastes, Biomass and Coal using High Temperature Steam Gasification

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1. Introduction

The increased energy demand and dwindling fossil fuel reserves necessitate the development of alternative fuel technologies. Crude oil, natural gas and coal reserves are finite so that one must find alternative renewable sources. Furthermore, at present oil and natural gas together constitute almost 50% of the world's energy sources. This then means that we can anticipate replacing almost half of our energy production with alternative sources of energy in the near term.

One of the attractive alternative fuels, which have been given considerable attention, is hydrogen. Despite being considered the cleanest fuel, hydrogen is still produced through processes, which causes environmental pollution, such as methane-steam reforming, which produces substantial amounts of carbon dioxide and other pollutants and uses useful energy resources, such as hydrocarbon fuels. Gasification, a process of converting solid fuel or waste into syngas under oxygen-starved conditions, has been known as a promising technology capable of producing hydrogen-rich fuel from solid feedstock, such as, biomass, solid waste and coal. The syngas produced is of low to medium calorific value and is rich in hydrogen and carbon monoxide. This technology greatly reduces tars and organic material in the residue and also minimizes the production of carbon dioxide and hydrocarbons which are directly responsible for the global warming from greenhouse gases as well as depletion of ozone. This study focuses on the high and ultra-high temperature steam gasification of paper, woodchips and coal to produce hydrogen-rich syngas while minimizing pollutant emissions, hydrocarbons, tars and solid residue in the products.

2. Key Features

Pure steam gasification was chosen over steam/air or steam/oxygen gasification (also called "unbound oxygen" gasification), because it was shown in previous studies [1,2] that it can maximize hydrogen yield while keeping carbon dioxide to a minimum. Furthermore, the use of high temperature favors enhanced hydrogen production and reduces tars, carbon dioxide and hydrocarbons. The Table below provides ultimate analysis of the raw feedstock materials examined here.

Materials	Ultimate Analysis [wt (%) dry]				
	C	H	O	N	S
Paper	49.0	6.9	35.0	0.5	0.1
Woodchips	52.6	7.0	40.1	0.0	0.0
Coal	83.3	5.4	8.1	1.6	1.6

Nominal sample weight for each sample of the material examined was about 30 grams. The steam flow rate was varied between 3.3 g/min and 6.3 g/min to analyze the effect of steam/feedstock ratio on the composition of the syngas. The temperature of the steam gasifying agent was varied between 700 to 1200°C.

Fig. 1 shows the syngas composition from the gasification of paper. It can be seen that hydrogen and carbon monoxide production increases with increase in gasification temperature, while production of methane and carbon dioxide decreases. Almost no methane or any higher series of hydrocarbons are present for the highest experimental gasification temperatures. Hydrogen and carbon monoxide concentration is expected to be the high at high gasification temperatures due to the endothermic nature of the water-gas and Boudouard reactions. Also, the endothermic steam-methane reforming reaction contributes to three moles of hydrogen from each mole of methane. Fig. 2 shows the lower heating value of the syngas produced from the gasification of paper, woodchips and coal using primarily the hydrogen, CO and methane gas produced since the amounts of other gases produced was in trace amounts. The heating value in the case of paper increases somewhat with increase in the gasification temperature. However, for the case of woodchips and coal, no change in heating value is observed.

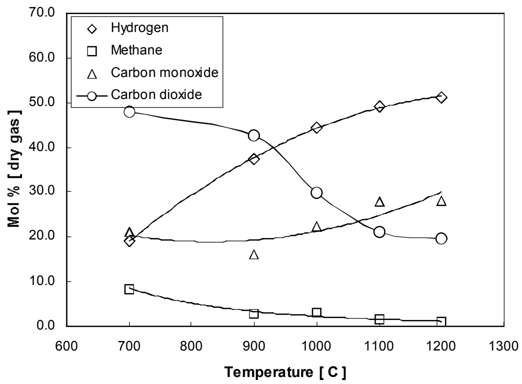

Fig. 1. Syngas composition from the gasification of paper at different temperatures.

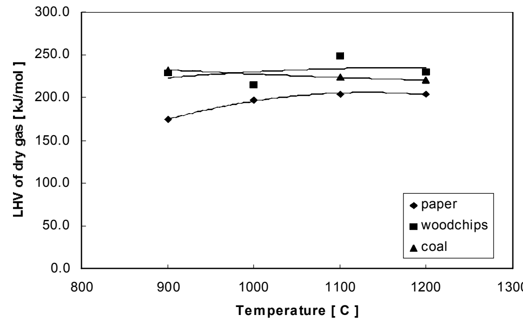

Fig. 2. Lower heating value of the syngas produced from gasification.

The amount of tar generation from gasification of paper, woodchips and coal was also measured to examine the effect of steam temperature on the total tar yield. Tar is an undesired product from any gasification or pyrolysis process. However, in the pyrolysis process the yield of tars can be quite high so that measures must be taken to control this product in the gasification process. It is formed during pyrolysis of solid fuel (at fuel temperature of 300°C to 620°C) and it consists of heavy hydrocarbons, which condense upon cooling to ambient conditions. Tar is responsible for corrosion of gasifiers and its deposits can clog channels which are difficult to remove. High gasification temperatures significantly reduce the tar yields.

3. Conclusions

The results from this study have shown that high temperature steam gasification process is capable of producing syngas containing up to 60% hydrogen with minimal CO_2 and hydrocarbons. At sufficiently high gasification temperatures, tar production can be almost eliminated from the gasification products, thus making the process attractive for the clean conversion of wastes and other solid hydrocarbon materials to clean syngas with high hydrogen content. The process is particularly attractive for solid wastes since the amount of tars produced is significantly reduced at increased gasification temperatures.

4. References

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