# Kinetic Study of High Temperature Steam Gasification of Biomass

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## 1. Introduction

Gasification is also a flexible process of converting carbon and volatile matters in biomass into a fuel gas consisting of mainly gaseous products such as hydrogen, carbon monoxide, methane and carbon monoxide with the use of some gasifying agent. The exact composition of the gases produced depends on the gasifying agent and the operational conditions. In order to achieve the high hydrogen yield, it is necessary to understand the chemical kinetics of gasification. This reaction can occur under controlled conditions of both temperature and pressure at sufficient residence time. The main reactions that occur during the gasification process are partial combustion reactions and gasification reactions. The partial combustion reactions react with free oxygen and are essentially complete under gasification conditions. These reactions are exothermic reaction and their roles are to give energy for the gasification reactions, endothermic reactions. The biomass gasification consists of two important steps of (i) initial rapid pyrolysis (devolatilization) to produce char, tar and gases, and (ii) subsequent gasification of the char generated. The char consists of carbon, hydrogen, oxygen, ash and a small amount of hetero-atoms such as N and S. The char gasification step has much slower reaction rate when compared with the rapid pyrolysis step. It is, therefore, considered as the controlling parameter for the overall conversion process. Most of the char gasification data reported in the literature has been obtained from coal gasification process and this is very different form the pyrolysis conditions. In this paper data has been obtained on the chemical kinetics of gasification of selected biomass and wastes as this is important for the syngas produced.

## 2. Key Features

The samples of paper and yellow pine woodchips were have been examined here with steam gasification using a specially designed experimental facility. High temperature steam is produced from the stoichiometric combustion of hydrogen and oxygen in a combustion chamber. The steam at the desired temperature is allowed to flow through the test section containing the sample feedstock. The steam flows into the electrically heated furnace, which maintains a constant temperature of the gasifying agent. 10 gram of sample was placed into a basket and inserted into a 2 ¼" diameter tube located in the furnace. The temperature of the gasifying agent was varied between 700°C and 900°C and steam mass flow rate was 3.3 g/min. Inert argon gas was used to stop reaction after reaching the desired reaction time. The solid char remaining was cooled with the inert gas from reaction temperature to ambient temperature. The syngas composition was analyzed with a Micro Gas Chromatograph. A set of thermocouples were used to monitor the temperature at various locations in the process. Fig. 1 show the char yields from both pyrolysis and steam gasification as a function of reaction time, t, at reaction temperature 700 °C.

The results show rapid decrease of char yield from pyrolysis at reaction time from 0 to 100 seconds, and after that they remain nearly constant at 16% from reaction time of 100 to 600 sec. This suggests that the pyrolysis process was complete within 100 seconds at 700°C for wood chip steam gasification. Char yields from steam gasification continuously decreased from 0 to 100 seconds at this reaction temperature. The evaluated kinetic parameters from this study are given in Table 1.

The values of char yields at various temperatures in the previous section were used to calculate the conversion, $X$ (dry-ash free basis), using the following equation:

$$X = 1 - \left[ \frac{W_{char} - W_{moisture} - W_{ash}}{W_{raw} - W_{moisture} - W_{ash}} \right] \quad \text{[dry-ash free basis]}$$

For steam gasification the values of conversion versus the progress of reaction time is shown in Fig. 2.

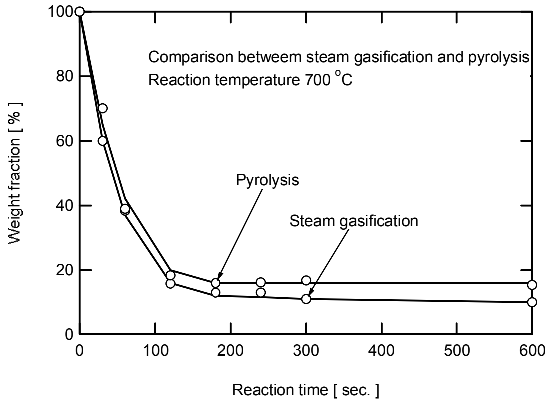


Fig. 1. Weight fraction of wood chips from steam gasification and pyrolysis at 700°C and 1 atmosphere.

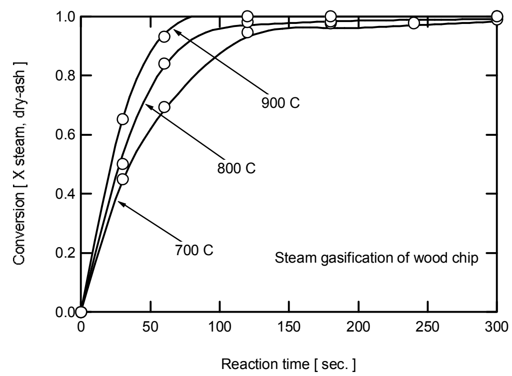


Fig. 2. Conversion of wood chips [dry ash bash] for steam gasification at 700, 800 and 900 ºC.

Table 1. Kinetic parameters for steam gasification of woodchips and paper, based on the homogeneous model.

| | k0 [s-1] | E [kJ/mol] |
|---|---|---|
| Woodchips | 10029 | 117.2 |
| Paper | 3.2 | 69.6 |

## 3. Conclusions

Gas products from steam gasification of woodchips and paper at various times have been examined. It was found that the gas yield is strongly affected by the steam to feedstock ratio, as the amount of feedstock decreases with time. The highest hydrogen yield was observed at the longest measured residence time of 180 sec. Relationships between gas composition in dry gas, solid remaining and time from steam gasification of woodchips and paper have been obtained.

## 4. References

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## Author Biographies

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