Gas and Tar Formation Characteristics in the Gasification Process for Biomass Materials

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INTRODUCTION

In the face of global warming and its serious consequences in recent years, it is an urgent task to steadily promote decarbonization in a wide range of fields. Energy recovery in waste treatment, called waste-to-energy (WtE), is a crucial issue in this field. In this context, thermal gasification has been a very attractive process for disposal and further utilization of potential biomass waste. This process provides H_2, CO, CO_2 and CH_4 as major components, which can be further converted to other chemicals. The classification of such gasification technologies and historical matters in the area of waste treatment have been reviewed in Japan (Kawamoto and Lu, 2016). However, no widespread practical application of this process has been seen, at least so far. Although there are real problems such as cost, the problem of tar formation and its adverse effect on plant equipment etc., which is a major by-product, is considered to be a big technical factor to be solved. In this study, the research results on tar formation and control are reviewed and summarized based on literatures. Then, the results of tar formation characteristics from a small-scale experiment are shown. The final goal is to realize and disseminate a gasification process for biomass and biomass-based waste.

EXPERIMENTAL

Materials

A woody biomass sample made from Japanese cedar and others was used as raw material for the gasification experiment, and the analysis data of the property is shown in Table 1 (Inoue et al., 2019). A catalyst material was used in some experimental conditions. The catalyst was composed of nickel (Ni) on originally prepared mesoporous silica base material called Ni/SBA-15.

Table 1 Proximate and ultimate analyses of the raw material

Analysis item	Value
Proximate analysis	
Moisture (%)	7.7
Volatiles (wt% dry)	84.9
Fixed carbon (wt% dry)	14.8
Ash (wt% dry)	0.3
High heat value (MJ/kg dry)	20.6
Low heat value (MJ/kg dry)	19.1
Ultimate analysis	
C (wt% dry)	51.4
H (wt% dry)	6.3
O (wt% dry)	41.9
N (wt% dry)	0.1
Cl (mg/kg dry)	<0.01
S (mg/kg dry)	<0.01

Apparatus and experimental procedure

Experiments were conducted by using a batch type apparatus as shown in Figure 1. The biomass sample (1 g) and the catalyst (1 g) when it is used was set in the reaction tube, then heated. After reaching 150 ºC, the carrier gases flowed out and the total emitted gas was sampled in a sampling bag and the composition was

measured by the TCD - GC for the determination of H_2 and other components. Tar constituents were trapped by using 2-propanol for the gravimetric measurement and PAH analysis was performed by a GC-MS.

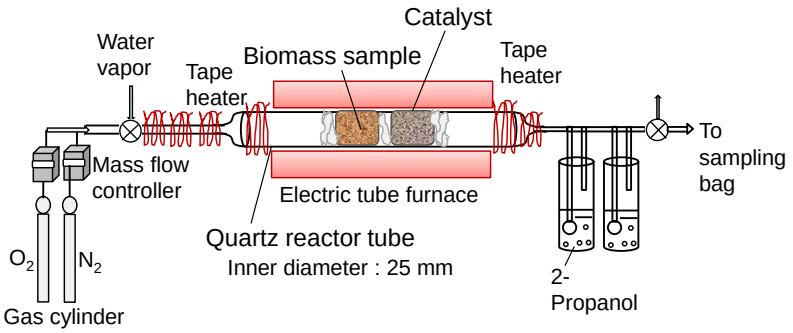

Figure 1 Batch type gasification experimental apparatus

RESULTS AND DISCUSSION

Tar formation in previous studies

Tar composition is affected by many factors; type of biomass, type of gasifier, and operating conditions which are temperature, ER and S/C etc. Aljbour and Kawamoto (2013) found that over the range of operating conditions tested, the tar content in the product gas ranged from 33 to <1 g/Nm^3, and higher temperatures, along with sufficient contact time can assist in PAH reduction. Kawamoto and Lu (2016) found that the tar concentration determined by gravimetric method decreased as the NiO content in the catalyst increased and the removal ratio reached almost 100 % with PAH and phenolic compounds.

Effect of technical parameters on syngas production and tar

From the batch type experiment, the temperature dependency of tar formation was well observed, as shown in Figure 2. In the condition of partial oxidation (ER;2.0), temperatures above 850 ºC efficiently reduced tar formation. However, the application of the catalyst showed similar tar resolution below 850 ºC. Further, the application of steam at the condition of S/C:2.5 reduced the tar amount to 0.14g/g-biomass at 750 ºC.

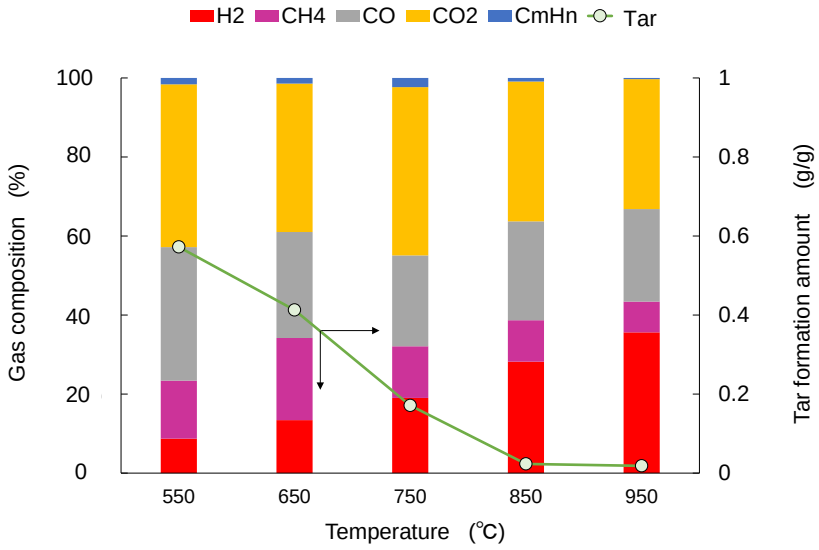

Figure 2 Gas composition and tar formation change in different temperatures in a batch type experiment (ER: 0.2, S/C: 0)

These findings suggested that the investigation for appropriate conditions would enable sufficient tar reduction due to the economical operating temperature.

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