Available online at www.sciencedirect.com

ScienceDirect

Procedia Environmental Sciences 31 (2016) 505 – 513

Procedia Environmental Sciences

The Tenth International Conference on Waste Management and Technology (ICWMT)

Study on Characteristics of Synthesis Gas Generation during Catalytic Gasification of Municipal Solid Waste

Wei Wu*, Xianchao Zhou, Peng Zhang,Wei Liu, Deji Danzeng, Shaozhuo Wang, Yamiao Wang

School of Materials and Metallurgy, Northeastern University, Shenyang City 110819, China

Abstract

This paper focuses on the effect of Ni-based reforming catalyst on tar decomposition, dealing with the relationship between the operating factors with synthesis gas composition. A series of catalytic gasification experiments of municipal solid waste were carried out under the range of 873-1023K, to evaluate the performance of three types Ni-catalyst on promoting H_2 and CO generation, particularly concerning with H_2/CO ratio variation. Tar generation characteristics relating to operating elements were discussed, and catalytic promoter inhibiting H_2S, SO_2 occurs was investigated. It indicated that Ni catalyst can effectively improve tar decomposition, promotes H_2 and CO generation. High temperature is favour for gasification and deep thermal crack, moreover improve the catalytic performance. Tar is finally converted into unsaturated hydrocarbons and oxy-organics. As catalyst promoter, alkaline metals, such as K, Ca, Zn presenting in Ni catalyst will significantly eliminate H_2S, promote tar decomposition, furthermore, directly affect the H_2 and CO ratio. Alkaline metal additives contained Ni-based catalysts be suggested as a potential means for the efficient production of clean synthesis gas from municipal solid wastes.

Peer-review under responsibility of Tsinghua University/ Basel Convention Regional Centre for Asia and the Pacific

Keywords: Synthesis gas; Municipal solid waste; Gasification; Reforming; Catalyst

1. Introduction

Currently, increasing volumes of municipal solid waste (MSW) pose disposal problems for many cities in China. Costs are rising as landfill becomes more difficult. Widespread public concern over emissions of polychlorinated dibenzo-p-dioxins and polychlorinated dibeno-furans (PCDDs/PCDFs) is an important reason for public opposition to

* Wei WU. Tel.: +024-83670467; fax: +024-83670467.
*E-mail address:*wuwei@smm.neu.edu.cn

Peer-review under responsibility of Tsinghua University/ Basel Convention Regional Centre for Asia and the Pacific
doi:10.1016/j.proenv.2016.02.067

incineration of MSW.

The production of clean gaseous fuels from MSW is one economically and environmentally promising option for dealing with these problems. Gasification of MSW is an alternative technology to produce fuels, declining the volumes and sufficiently harmful[1]. Gasification refers to the thermo-chemical conversion of combustible materials into synthesis gases with the key components such as hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), and lighter hydrocarbons (C_nH_m) at high temperature condition. Nowadays, Gasification systems are successfully applied to the production of energy from biomass[2]. We also expect that gasification can represent an attractive alternative to the well-established thermal treatment systems for the recovery of renewable energy from municipal solid wastes[3].

Gasification technology of solid wastes has comprehensively investigated and made significant advances in the past 30 years. Various demonstrate plants and commercial processes have been built[4,5]. The demonstrated results of these gasification process indicated that environmental benefits of fuels production from MSW would be substantial compared with incinerations. Particularly, the production hydrogen-rich synthesis gas from MSW via gasification has received serious recent attention. High efficiency electricity generation is expected to be achieved by directly chemical conversion incorporated with fuel cells or produce derived fuel by Fischer-Tropsch synthesis to meet transportation needs[6]. However, for the production of hydrogen-rich synthesis gas, MSW would first be require to removal of no-combustible elements, following by sizing and mixing of the remaining components into refuse derived fuel (RDF). After gasification, trace contaminants in the product gas must be removed to prevent poisoning of catalysts in downstream reactors. This constraint ensures that fuels production from MSW has low external environmental impacts. Key contaminants of concern are sulphur, chlorine, particulates, heavy metals, halide gas, tar and so on during gasification. A typical cleanup process might first involve particulate removal with a cyclone and quenching in a wet scrubber. If needed, the concentration of halide gases (e.g. HCl and HF) can be further reduced by injection of an alkaline solution. Sulphur leaves a gasifier largely as hydrogen sulphide (H_2S). It can be removed using commercial low temperature processes and converted in elemental sulphur[7].

In order to produce hydrogen-rich synthesis gas, adjusting the ratio of H_2 to CO, as well as eliminating tar and the other trace contaminants at low temperature process, a catalytic reforming unit is normally set in the downstream. Since the catalysts used in Fischer-Tropsch (F-T) synthesis and fuel cell have a very low tolerance for contaminants, their concentrations must be much lower than those reflected in public-health based emissions regulations. For example, 100 ppmH_2S will poison the catalysts used in F-T process. The low emissions of contaminants to the air with gasifier-based fuels production from MSW suggest that contaminant concentrations in liquid and solid effluents should also be examined carefully. Comprehensive emissions data (solid, liquid, and gaseous) that would allow a more careful assessment were not only collected during the tests, but also the results of the waste water tests suggest that pollutants in liquid effluents will be minimal from fuels production[8].

Catalytic gasification-reforming has been well known as favour for more of H_2 and CO generated at rather lower temperature condition. Moreover, it has been demonstrated that hydrogen-rich synthesis gas can be effectively produced from the gasification of wood and plastic with using Ni-based reforming catalysts[9-11], as well as noble metals such as Rh, Ce, and these metals exhibited excellent catalytic performances and are less susceptible to carbon deposition[12]. Unfortunately, these metals considered unfeasible for commercialization due to expensiveness and lack of deposits. It is considered more economic and feasible for commercialization using alkali metals oxides as catalyst, such as CaO, ZnO, as well as natural mineral, such as dolomite and olivine[13,14].

In this study, RDF was subjected to directed gasification and catalytic reforming in order to obtain feasible synthesis gas at 873, 923, 973 and 1023K, respectively, and gaseous products propose to be used in the process of F-T synthesis for derived fuel production. Our experimental research focused on the effect of Ni-based reforming catalysts on tar decomposition, dealing with the relationship between the operating factors with synthesis gas composition, and evaluate the performance of three types Ni-catalyst on promoting H_2 and CO generation, particularly concerning with H_2/CO ratio variation.

Since synthetic derived fuel is proposed as the end-used in our study, only the synthesis gas with rather high content of H_2 and CO available for raw mater. Furthermore, taking account of derived fuel synthesis operating condition and tolerance levels of synthesis catalyst for trace contaminates, the gasification process would desirably be operated under a range from 873-1023K and followed with a high temperature purification unit to avoid unnecessary heat losses caused by temperature variations between the gas producing process and synthesis process. In this study,