GASIFICATION OF OIL SLUDGE AND PETROCOKE BY DETONATION METHOD

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Abstract: A new technology for gasification of organic waste with a high-temperature gasifying agent (GA) based on gaseous detonation products of a methane–oxygen mixture with temperatures above 1500–2000 °C is used for gasification of three types of oil sludges: ground oil sludge, tank oil sludge, and petcoke — a product of secondary oil refining, which are mixtures of branched aliphatic hydrocarbons with a small amount of aromatic hydrocarbons, contain large amounts of carbon (77–85 %(wt.)) and sulfur (2.1–3.5 %(wt.)) and have a higher heating value of 28–36 MJ/kg. Experiments show that dry gasification products contain 80–90 %(vol.) combustible gas which contains 40%–45% CO, 28%–32% H_2, 5%–10% CH_4, and 4%–7% noncondensable C_2–C_3 hydrocarbons. The gasification process is accompanied by the removal of mass from the reactor in the form of ultrafine solid ash particles with a size of about 1 μm. Ash particles have a mesoporous structure with a specific surface area from 3.3 to 15.2 m^2/g and a wide range of pore sizes from 3 to 50 nm. The measured wall temperatures of the gasification reactor (600–630 °C) are in good agreement with the calculated value of the thermodynamic equilibrium temperature of the gasification products (approximately 730 °C). The measured CO content in gasification products is in good agreement with thermodynamic calculations and the reduced H_2 content and increased CH_4, CO_2, and C_xH_y contents are apparently associated with the nonuniform distribution of the waste/GA mass ratio in the gasifier. To increase the yield of hydrogen, it is necessary to improve the mixing of waste with GA. It is proposed to mix crushed petcoke with oil sludge to form a paste and feed the combined waste into the gasifier using a specially designed piston feeder.

Keywords: high-temperature gasification of organic waste; gaseous detonation products; oil waste; gasification products; ash particles; mass loss

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Figure Captions

Figure 1 Photographs of oil wastes: (*a*) ground oil sludge; (*b*) tank oil sludge; and (*c*) petcoke

Figure 2 Infrared spectra of ground oil sludge (*a*) and tank oil sludge (*b*)

Figure 3 ^{1}H (*a*) and ^{13}C (*b*) nuclear magnetic resonance (NMR) spectra of ground oil sludge sample

Figure 4 ^{1}H (*a*) and ^{13}C (*b*) NMR spectra of tank oil sludge sample

Figure 5 Schematic of the experimental setup: *1* — mixing and ignition device; *2* — spark plugs; *3* — test section of the pulsed detonation gun (PDG); *4* — cooling system; *5* — gasifier; *6* — gas sampling system; *7* — ionization probes; *8* — valves for oxygen and fuel lines; *9* — reducers; *10* — pressure sensors; *11* — oxygen receiver; *12* — methane (natural gas) receiver; *13* — oxygen source; and *14* — methane (natural gas) cylinder

Figure 6 Photograph of a gasifier with an attached PDG (*a*) and a gas cleaning system (*b*)

Figure 7 Example of ionization probe records during PDG operation in 13 consecutive cycles (*a*) and an exploded view of one cycle (*b*)

Figure 8 Examples of thermocouple records in the gasifier wall (*1*) and in the gas in the upper part of the gasifier (*2*)

Figure 9 Gas analyzer records in an experiment with ground oil sludge

Figure 10 Gas analyzer records in an experiment with petcoke

Figure 11 Gas analyzer records in an experiment with the supply of a paste consisting of petcoke and tank oil sludge with a mass ratio of 1 : 1

Figure 12 The photograph of the ash extracted from the large and small cyclones of the gas cleaning system after the experiment (*a*), and size distributions of ash particles averaged over three samples (*b*) for four types of waste: *1* — ground oil sludge; *2* — tank oil sludge; *3* — petcoke; and *4* — tank oil sludge – petcoke (1 : 1)

Figure 13 Adsorption (filled symbols) and desorption (empty symbols) isotherms of nitrogen N_2 at 77 K for the studied samples of ash residue particles: *1* — ground oil sludge; *2* — tank oil sludge; *3* — petcoke; and *4* — tank oil sludge – petcoke (1 : 1) paste

Figure 14 Pore size distributions measured by the BJH (Barrett–Joyner–Halenda) method: *1* — ground oil sludge; *2* — tank oil sludge; *3* — petcoke; and *4* — oil sludge – petcoke (1 : 1) paste

Figure 15 Equilibrium parameters of dry products of oil waste gasification in the GA environment versus the waste-to-GA mass ratio. Gasifying agent is represented by the detonation products of a stoichiometric methane–oxygen mixture expanded to atmospheric pressure. The wide vertical bar corresponds to the waste-to-GA mass ratios in the experiment. Two narrow vertical bars conditionally show two possible local values of waste-to-GA mass ratios in the gasifier caused by the spatial nonuniformity of waste distribution

Table Captions

Table 1 Results of elemental analysis of oil waste samples

Table 2 Higher heating values of initial oil wastes

Table 3 Calculated composition of detonation products of a stoichiometric methane–oxygen mixture expanded to an initial pressure of $P_0 = 0.1$ MPa

Table 4 The summary table for all experiments performed

Table 5 Elemental analysis of ash residues of oil waste samples

Table 6 Higher heating values of ash residues from oil wastes

Table 7 Specific surface area and parameters of the porous structure of oil waste samples

Table 8 Characteristics of initial oil wastes

Table 9 Characteristics of ash residues from oil waste

Table 10 Results of granulometric analysis for three samples for four types of oil wastes

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