AUTOTHERMAL NATURAL GAS CONVERSION AND ALLOTHERMAL GASIFICATION OF LIQUID AND SOLID ORGANIC WASTES BY ULTRASUPERHEATED STEAM

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Abstract: The technology of a pulsed-detonation gun for gasification of organic waste with ultrasuperheated steam has been experimentally demonstrated for the first time. The experiments on autothermal natural gas conversion as well as on the allothermal gasification of liquid (waste machine oil) and solid (sawdust) wastes by the products of pulsed detonation of natural gas – oxygen mixture at a pulse frequency of $f = 1$ Hz were conducted. At such a frequency, the time-averaged mean temperature and absolute pressure of detonation products in a flow reactor attached to the gun were about 1200 K and 0.1 MPa, respectively. The technology of the pulsed-detonation gun was shown to provide complete (100%) conversion of natural gas in fuel-rich natural gas – oxygen mixture into syngas containing H_2 and CO with an H_2/CO ratio of about 1.25. Gasification of liquid and solid wastes led to the production of syngas containing up to 80 and 65 %(vol.) (dry basis) reactive components (H_2, CO, and CH_4) with H_2/CO ratios of 0.8 and 0.5, respectively. Comparison of syngas compositions obtained in experiments with fuel-rich natural gas – oxygen mixtures and in experiments with gasification of liquid and solid wastes under the same conditions at $f = 1$ Hz and 0.1 MPa showed that these compositions almost did not depend on the feedstock type.

Keywords: natural gas; autothermal conversion; organic waste; allothermal gasification; steam; carbon dioxide; pulsed detonation gun; ultrasuperheated steam

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Figure Captions

Figure 1 Schematic of a detonation waste converter (*a*) and flow structure in a reactor (*b*)

Figure 2 Calculated time histories of the mean steam temperature in the reactor during steady-state operation of the detonation waste converter at a frequency of $f = 5$ (*1*) and 1 Hz (*2*) without waste supply: wall temperature $T_w = 450$ K and pressure $P = 0.1$ MPa

Figure 3 Calculated time histories of the mean temperature in the reactor during steady-state operation of the detonation waste converter at a frequency of $f = 5$ Hz without waste supply ($P = 0.1$ MPa): *1* — $T_w = 800$ K; *2* — 650; and *3* — $T_w = 450$ K

Figure 4 Example of ionization probe records in one operation cycle of the pulsed detonation gun

Figure 5 Variation of the detonation velocity (averaged over several operation cycles) along the tube

Figure 6 Change in the composition of cooled dry detonation products of natural gas / O_2 mixture with a stepwise variation of fuel-to-oxygen equivalence ratio Φ in the mixture at $f = 1$ Hz and $P \approx 0.1$ MPa

Figure 7 Measured composition of cooled dry detonation products of natural gas / O_2 mixture at various values of Φ ($f = 1$ Hz and $P \approx 0.1$ MPa). The measurement errors are shown only for the extreme values of Φ

Figure 8 Comparison between measured (symbols) and calculated (curves) concentrations of cooled dry detonation products of natural gas / O_2 mixture. The calculation was performed for the composition “freezing” temperature 2200 K

Figure 9 Calculated compositions of detonation products of natural gas / O_2 mixtures with different values of Φ at the composition “freezing” temperature 2200 K ($f = 1$ Hz and $P = 0.1$ MPa)

Figure 10 Measured composition of cooled dry gasification products of liquid waste vs. the mass flow rate of waste at $f = 1$ Hz and $P \approx 0.1$ MPa

Figure 11 Primary records of changes in the composition of cooled dry syngas in experiment with solid waste (sawdust) at $f = 1$ Hz and $P \approx 0.1$ MPa

Figure 12 Compositions of syngas obtained in experiments on natural gas conversion (*1*) and on gasification of liquid (*2*) and solid (*3*) wastes under the same conditions ($f = 1$ Hz and $P \approx 0.1$ MPa)

Figure 13 Calculated time histories of the maximum steam temperature in the reactor during steady-state operation of the detonation waste converter with $f = 1$ (*1*) and 5 Hz (*2*) without waste supply ($T_w = 450$ K and $P = 0.1$ MPa). The horizontal lines correspond to the time-averaged mean temperatures in the reactor

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