GASIFICATION OF LIQUID HYDROCARBON WASTES BY HIGH-TEMPERATURE PRODUCTS OF GAS DETONATION: THERMODYNAMIC CALCULATIONS OF THE COMPOSITION AND TEMPERATURE OF THE RESULTING SYNGAS

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Abstract: The gasification process of liquid hydrocarbon waste (LHW) in the flow of a high-temperature gasifying agent (GA) is modeled thermodynamically. The source of the GA is a pulsed detonation gun (PDG). The GA is composed of the ultrasuperheated mixture of steam and carbon dioxide with the temperature of detonation products in the Chapman–Jouguet (CJ) state or those expanded to atmospheric pressure. Methane and syngas obtained as a result of LHW gasification are used as fuels for the PDG. To optimize the composition of the product syngas, the effect of diluting the fuel–oxygen mixture with steam in the PDG is considered. Thermodynamic modeling shows that gasification of LHW with detonation products allows achieving complete conversion of LHW into the syngas consisting exclusively of hydrogen and carbon monoxide or into the energy gas with high concentrations of methane and C_2–C_3 hydrocarbons and a lower heating value ranging from 36.7 (for mixtires with oxygen) to 13.6 MJ/kg (for mixtures with air). The resulting syngas mixed with oxygen can be used for self-feeding of the PDG: about 33% of the product syngas is then directed for self-feeding. To self-feed the PDG with a mixture of the product syngas and air, it is necessary to increase the pressure in the reactor and/or enrich the air with oxygen. The addition of low-temperature steam to the initial combustible mixture allows variation of the composition of the product syngas within a wide range. Theoretically, the H_2/CO ratio can be varied from 1.3 to 3.4.

Keywords: pulsed detonation gun; ultrasuperheated mixture of steam and carbon dioxide; liquid hydrocarbon waste; gasification; syngas

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Figure Captions

Figure 1 Four models of the gasification process: (*a*) model 1 with the supply of feedstock to the PDG without syngas self-feeding; (*b*) model 2 with the supply of feedstock to the reactor-gasifier without syngas self-feeding; (*c*) model 3 with the supply of feedstock to the PDG with syngas self-feeding; and (*d*) model 4 with the supply of feedstock to the reactor-gasifier with syngas self-feeding

Figure 2 Equilibrium states of detonation products of the stoichiometric methane–oxygen mixture — from values at the CJ point (circles) to values corresponding to $P_0 = 1$ bar (squares): solid curves — component volume fractions; and dashed curve — temperature

Figure 3 Equilibrium states of detonation products of the stoichiometric methane–oxygen mixture with steam dilution from 0 to 40 %(vol.) in the CJ state (*a*) and after expansion to $P_0 = 1$ bar (*b*): solid curves — component volume fractions; and dashed curve — temperature

Figure 4 Equilibrium states of detonation products of the stoichiometric methane–air mixture — from values at the CJ point (circles) to values corresponding to $P_0 = 1$ bar (squares): solid curves — component volume fractions; and dashed curve — temperature

Figure 5 Calculated dependence of CJ detonation velocity (*a*) and temperature of the detonation products at the CJ point (*1*) and the detonation products expanded to $P_0 = 1$ bar (*2*) (*b*) on the oxygen concentration in air

Figure 6 Equilibrium parameters of the dry products of LHW gasification as a function of the LHW-to-GA mass ratio; GA is represented by the detonation products of the stoichiometric methane–oxygen mixture in the CJ state (*a*) and expanded to atmospheric pressure (*b*): solid curves — component volume fractions; and dashed curves — temperature. The arrows show the compositions of gasification products with the maximum content of hydrogen and methane

Figure 7 Equilibrium parameters of the dry products of LHW gasification as a function of the methane dilution with steam with GA parameters at the CJ state (0.53 kg/kg, solid curves) and $P_0 = 1$ bar (0.45 kg/kg, dashed curves)

Figure 8 Equilibrium parameters of the dry products of LHW gasification as a function of the LHW-to-GA mass ratio; GA is represented by the detonation products of the stoichiometric methane–air mixture in the CJ state (*a*) and expanded to $P_0 = 1$ bar (*b*): solid curves — component volume fractions; and dashed curves — temperature. The arrows show the compositions of gasification products with the maximum content of hydrogen and methane

Figure 9 Equilibrium parameters of the dry products of LHW gasification as a function of oxygen concentration in air; GA is represented by the detonation products of the stoichiometric mixture of methane with oxygen-enriched air; the LHW-to-GA mass ratio is 0.53 kg/kg: solid curves — component volume fractions; and dashed curves — temperature. The arrows show the compositions of gasification products with the maximum content of hydrogen and methane

Figure 10 Equilibrium parameters of the dry products of LHW gasification as a function of oxygen concentration in the air; GA is represented by the detonation products of the stoichiometric mixture of methane with oxygen-enriched air expanded to $P_0 = 1$ bar; the LHW-to-GA mass ratio is 0.45 kg/kg: solid curves — component volume fractions; and dashed curves — temperature. The arrows show the compositions of gasification products with the maximum content of hydrogen and methane

Figure 11 Equilibrium parameters of the dry products of LHW gasification as a function of oxygen concentration in the air; GA is represented by the detonation products of the stoichiometric syngas ($H_2/CO = 1.3$) – oxygen – nitrogen mixture; the LHW-to-GA mass ratio is 0.53 (*a*) and 0.45 kg/kg (*b*): solid curves — component volume fractions; and dashed curves — temperature. The arrows show the compositions of gasification products with the maximum content of hydrogen and methane

Table Captions

Table 1 Parameters of the LHW gasification process with self-feeding of the PDG with the stoichiometric mixture of the product syngas and oxygen (model 3)

Table 2 Parameters of the LHW gasification process with self-feeding of the PDG with the stoichiometric mixture of the product syngas and oxygen (model 4)

Table 3 Parameters of the LHW gasification process with self-feeding of the PDG with the stoichiometric mixture of the product syngas and air (model 3)

Table 4 Self-feeding of the PDG with the stoichiometric mixture of the product syngas and oxygen: comparison of dry syngas parameters calculated by models 3 and 4 and by Eq. (1)

Table 5 Self-feeding of the PDG with the stoichiometric mixture of the product syngas and air: comparison of dry syngas parameters calculated by model 3 and by Eq. (3)

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