*35th EPS Conference on Plasma Phys. Hersonissos, 9 - 13 June 2008 ECA Vol.**32D**, O-2.018 (2008)*

PLASMA GASIFICATION OF COAL AND PETROCOKE

O.A.Lavrichshev, V.E.Messerle, E.F.Osadchaya, A.B.Ustimenko*

Research Institute of Experimental and Theoretical Physics, Almaty, Kazakhstan

**Corresponding author e-mail: ust@physics.kz*

Coal is worldwide most abundant energy resource and the least expensive fossil fuel. One more energy resource is petrocoke derivable as a result of hydrocarbons production by oil sands thermal processing. Petrocoke is a solid fuel consisting of fixed carbon, tar and ash. Direct utilization of petrocoke is difficult because of its hardness and high tar content. In connection with this, the development of solid fuels technologies, which would be environmental friendly and efficient, is of a primary importance. Coal gasification is a well-proven technology that started with the production of synthesis gas ($CO + H_2$) for urban areas. Gasification-based technologies can be used to convert carbon-containing resources into a clean syngas as a fuel for combined cycle power generation [1] or as a raw material for the production of liquid fuels and chemicals. Plasma gasification of solid fuels is one of the perspective technologies for effective and environmentally friendly solid fuels use [2].

1. Numerical Simulation

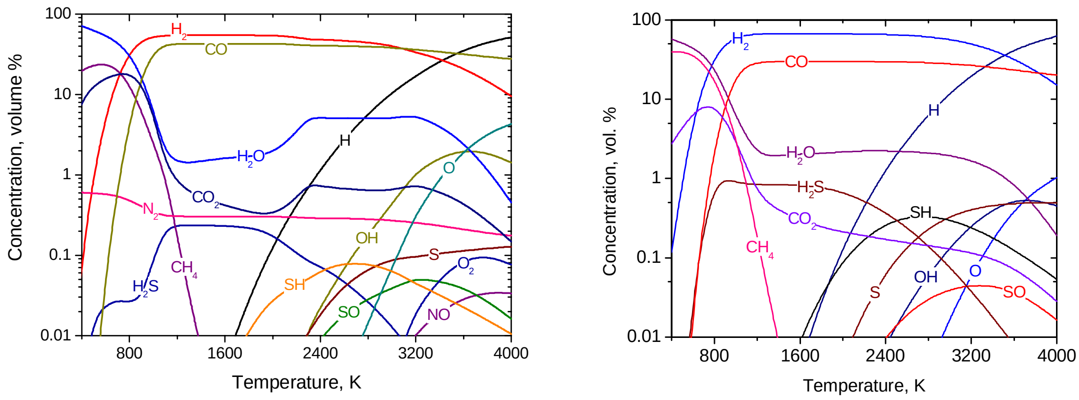
Code TERRA [2] was used for thermodynamic analysis of the pulverized fuels (pf) plasma gasification process. TERRA has its own database of thermodynamic properties for more than 3500 chemical agents over a temperature range of 300 to 6000 K. The calculations were performed for the process of Kuuchekinski bituminous coal (KBC) and Canadian petrocoke (CP) gasification in steam medium. The chemical composition of the solid fuels is presented in Table 1. The calculations were performed for atmospheric pressure and within temperature interval 400-4000K. The temperature is suggested to be kept at the expense of external heat source, which is an arc in the gasifier. The initial compositions of the variants of the technological systems for calculations are following: 100 kg of KBC + 62.75 kg of water steam and

100 kg of CP + 120 kg of water steam. The estimate of the steam requirement was made from the water gas reaction.

Table 1. Solid fuels chemical analysis, % dry mass basis.

Solid fuel	C	O	H	N	S	SiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Al_2O_3
KBC	48.86	6.56	3.05	0.8	0.73	23.09	2.15	0.34	0.31	0.16	0.15	13.8
CP	75.0	0.88	15.53	0.01	5.63	1.31	0.6	0.1	0.05	0.07	0.04	0.78

Gas phase of the products of KBC gasification (Fig. 1 a) is presented generally by syngas, which the maximal concentration is 99 % at 1500 K. At that sum concentration of atomic and molecular hydrogen is higher than concentration of carbon monoxide all over the temperature range and varies from 48 to 59 % in volume. With the temperature concentration of carbon monoxide decreases from 47 % at 1500 K down to 34 % at 4000 K. At temperature above 2000K oxygen from mineral mass of coal starts actively to participate in the reactions of hydrogen, sulphur and nitrogen oxidation. It leads to their oxides formation and NO particularly. NO concentration reaches 350 ppm by T=4000K.



(a) (b)

Fig. 1. Composition of organic components in gas phase versus temperature at KBC (a) and CP (b) steam gasification.

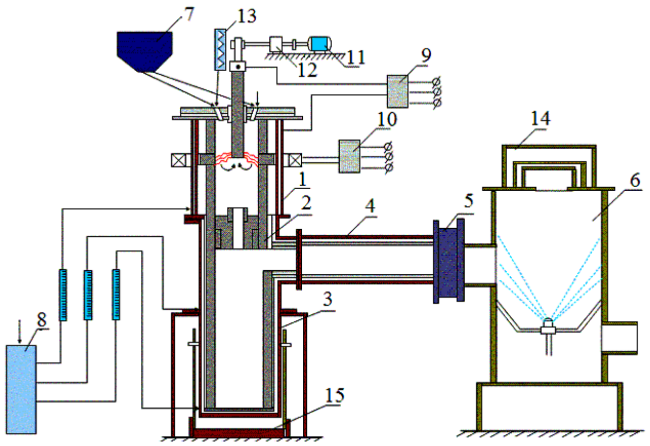
Gas phase of the products of CP gasification in a temperature interval of 1200 to 2800 K (Fig. 1 b) mainly consists of syngas. When the concentration of hydrogen was about

67% (T=1400K), the concentration of carbon monoxide was about 29.8% and sulfur was present as sulfur hydrogen (about 0.8%). The oxidants concentration (H_2O and CO_2) is not exceed 2.5% in that temperature range. At temperatures greater than 2000 K atomic hydrogen is appeared in gas phase. Its concentration reaches 62.2% at the temperature 4000 K. At temperatures greater than 2200 K hydrogen sulfide dissociates into atomic sulfur and sulfur hydride with total maximal concentration of them reaching 0.5%. At temperatures greater 3000 K in gas phase hydroxyl and atomic oxygen is appeared. Their total concentration was less than 1.5%. Contrary to the previous case nitrogen oxides are not formed.

Carbon gasification degree increases with the temperature and reaches 100 % by the temperature 1200 K in the both cases.

2. Experiment

The experimental installation (Fig.2) is intended for work in the range of electric power 30-100 kW, mass averaged temperature 1800-4000 K, coal dust consumption 3-12 kg/h and water steam flow 0.5-15 kg/h. The steam/pulverised fuel mixture entering the arc zone is heated to high temperature by the arc rotating in electromagnetic field to produce a two-phase plasma flow where the solid fuel gasification process occurs.



1 – plasma gasifier; 2 – chamber of gas and slag separation; 3 – slag catcher; 4 – syngas cooling chamber; 5 – orifice; 6 – chamber of hydration; 7 – coal dust feeder; 8 – cooling system; 9, 10 – electric power supply system; 11, 12 – gear for rod electrode supply; 13 – steam generator; 14 – safety valve; 15 – stand for slag catcher.

Fig. 2. The scheme of plasma unit for solid fuel gasification.

The dust of KBC and CP (Table 1) was used in the experiments. The sieve analysis of the pf revealed that mean sizes of the KBC and CP dust particles were 75 µm and 105 µm correspondingly. The results of the experiments are shown in Table 2. Thermal efficiency of the reactor was determined as 76 % for the experiments. As a result of KBC and CP gasification under steam plasma conditions concentrations of gas species, specific power consumptions (SPC), carbon gasification degree X_C and mass-averaged temperatures T_{AV} in the reactor were revealed.

Table 2. Main Indexes of the Solid Fuels Plasma Gasification

N	Solid fuel	Consumption, kg/h fuel	Consumption, kg/h steam	P, kW	SPC, kW h/kg	T_{AV}, K	CO, Volume %	H_2, Volume %	N_2, Volume %	X_C, %
1	KBC	4.0	1.9	25	4.8	3500	41.5	55.8	2.7	94.2
2	CP	2.5	3.0	60	9.6	3850	36.2	63.1	0.7	78.6

Conclusions

Fulfilled study of two essentially different in composition and in quality solid fuels plasma steam gasification showed possibility to produce high quality syngas. Comparison between the calculated and experimental data showed satisfied agreement. The received syngas from the solid fuels is a high-quality power gas, and it can be used for synthesis of methanol and dimethyl ether. Syngas of this quality is high reactive reducing agent for iron ore direct reducing and can serve as a substitute of metallurgical coke. Plasma steam gasification is perspective method for hydrogen production through water steam decomposition by carbon of low-rank solid fuel.

References

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