Methane pyrolysis using water-stabilized hybrid plasma torch

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Abstract: Methane pyrolysis using water-stabilized plasma torch as a source of energy in the form of heat and active species was investigated at high gas flow rates in the range from 100 up to 500 slm and plasma torch power 120 kW. Methane conversion about 80% were reached. The ratio of H_2 to CO in the syngas was in the range between 7.4 and 14. The acetylene concentration was lower than 1%. The carbon black samples were obtained.

Keywords: Methane reforming, pyrolysis, gasification, thermal plasma, hybrid plasma torch.

1. Introduction

Pyrolysis is a process of thermal decomposition of complex compounds at oxygen deficit. This technique is widely used for obtaining of low-molecular hydrocarbons from petroleum. However, such method can be used also for fabrication of pure hydrogen or/and carbon black by decomposition of low-molecular organics (methane/nature gas for example).

In this case plasma can serve an appropriate source of energy for these reactions due to not only a high heat transfer, but a high concentration of active species (ions, radicals and so on) too. Some applies of DC arc plasma [1,2] and microwave plasma [3] were already investigated.

In this study we focused on the high-flowrate methane plasma pyrolysis in pilot gasification reactor using water-stabilized hybrid plasma torch.

2. Experimental part

Plasma torch with stabilization of the arc by a mixture of an inert gas and water vapour generated thermal plasma. A detailed description of an operation principle can be found elsewhere [4, 5]. Gas (in our case – argon) is supplied along an inner thin tungsten cathode and then arc stabilized in water vortex. Thus the plasma has no impurities which could contaminate the synthesis gas. A rotating copper disc with water cooling serves as outer anode [6].

The scheme of plasma gasifier PLASGAS is presented in Fig. 1 [7]. Plasma torch is placed at the top of the reactor. Temperature of inner surface is measured in several positions as showed below.

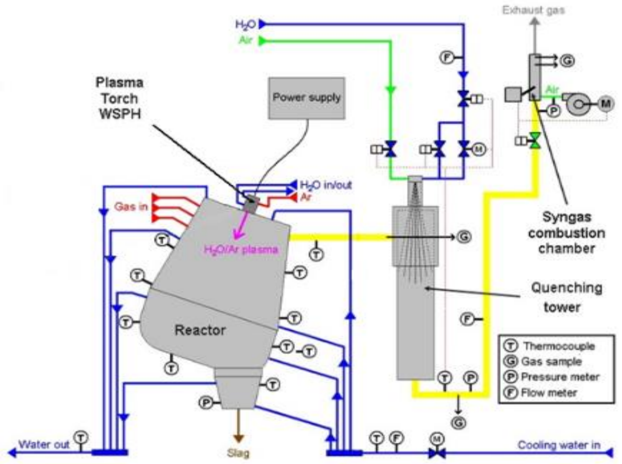

Fig. 1. Scheme of gasification reactor.

The flow rates of input gases were measured using mass flow controller AALBORG GFC-57. The syngas flow rate was determined from measured He concentration. The argon was added at known input flow rate. The argon flow rate was measured with accuracy better than 10%, the argon concentration in syngas was measured with an accuracy better than 1%. A quadrupole mass spectrometer Pfeiffer Vacuum Omnistar GSD 301 was used as a main gas analyzer.

Structure, morphology and chemical composition of obtained solid carbon samples will be studied by scanning electron microscope, x-ray diffraction and x-ray photoelectron spectroscopy.

The main experimental conditions are described in the table 1:

Table 1. Experimental conditions.

Arc current	400 A
Arc power	120 kW
Methane flow rate	100 – 300 slm
Calibration gas	Helium
Calibration gas flow rate	20-60 slm
Water vapour from the plasma torch	18 g/min

3. Results and Discussions

Chemical composition (% of mass fraction) of obtained synthesis gas in dependence on methane flow rate is presented in table 2.

Table 2. Syngas chemical composition.

CH_4 flow rate, slm	100	200	300
H_2	76.3	76.2	71.5
CO	10.3	7	5.1
CO_2	0.3	0.1	0
C_2H_2	0.9	0.4	0.4
Ar	1.2	0.7	0.5
O_2	0	0	0
CH_4	5	8.5	14.3
He	6	7.1	8.2

Methane conversion about 80% were reached. The ratio of H_2 to CO in the syngas was in the range between 7.4 and 14. The acetylene concentration was lower than 1%. Power 120 kW was already not enough for stable decomposition of methane with flow rate 500 slm.

4. Conclusions

DC arc plasma torches can be successfully used for effective gasification of low-molecular organic compounds for synthesis gas with high ratio of H_2/CO, pure hydrogen or carbon black production.

5. Acknowledgements

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6. References

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