MATHEMATICAL MODEL FOR CONTROLLING GASIFICATION PROCESS OF LIGNITE

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Abstract

Based on the results of the gasification process at the Baganuur and Shivee-Ovoo coal deposits, which are the main representatives of Mongolia's lignite, a mathematical model has been developed that can control the gasification process. Using this mathematical model of nonlinear regression, it is important to predict the composition of the combustible gas, the low heat value, and the volume of production, depending on the gasification pressure and temperature, the blowing agent

Introduction

Coal gasification is the process of forming combustible gases (CO, H_2, CH_4)[1] as a result of a chemical reaction between the carbon of the solid mass of coal and the gasification agents (air, water vapor, air + water vapor, oxygen, etc.)[2,3].

Researchers have found that intensive research and analysis since the beginning of the last century has laid the foundations for a modern physicochemical theory of solid fuel gasification.

Many Russian scientists, such as N.N Dobrokhotov, D.B Ginzburg, Z.F Chukhanov, G.I Deshalit, German scientist and engineer H. Finkbeiner, and American scientist and engineer Wilhelm Hums, played a leading role in this study. In their work, the gasification process in a gasifier is divided into the following main parts and zones.

These include:

- Combustion or oxidation zone
- Gasification and reduction zone
- Dry distillation or pyrolysis zone
- Drying or moisture separation zone

In the gasification process, direct reactions take place in the combustion or oxidation zone, while reverse reactions take place in the gasification or reduction zone.

In order for a gasifier to operate efficiently, the ratio of oxygen to water vapor (O_2 + H_2O/coal) and coal, as well as the ratio of oxygen to water vapor (O_2/H_2O), must be determined correctly[4]. This will increase the production of synthetic gases and increase the content of hydrogen and carbon monoxide in the combustion gases.

Methods And Materials

In our study, we selected a single-stage pressurized gasifier, a type of fixed bed gasification generator that produces combustible gas for energy from coal. The technological scheme of this gasifier is shown in Figure 2.

Due to the use of air and steam-air blowers in this type of gasifier, for energy combustible gas has a relatively low heat value (4-7 MJ/m^3) compared to other synthetic gases, and the standard composition of coal combustible gas [5] has the following structure and composition is.

These include:

- Carbon monoxide, CO - 25-31, %
- Carbon dioxide, CO_2 - 4-6, %
- Hydrogen, H_2 - 13-15, %
- Oxygen, O_2 -0-0.6, %
- Methane, CH_4 - 1.8-2.4, %
- Nitrogen, N_2 - 47-51, %

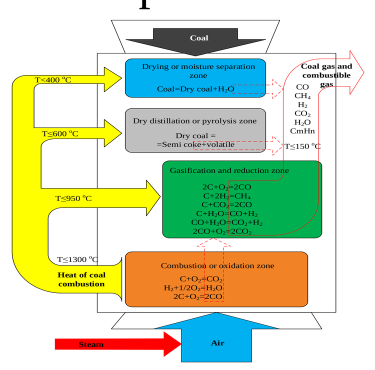

Figure 1. Gasification reactions and processes in gasifiers

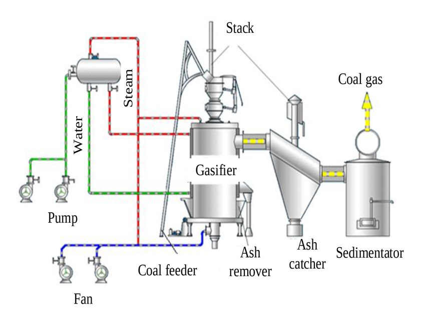

Figure 2 Technology scheme for coal gasification

The low heat value of combustible gases generated by coal gasification is calculated by the method developed by the famous Russian scientist DI Mendeleev.

$$Q_l^{\,w} = 30.25\cdot CO + 25.27\cdot H_2 + 85.55\cdot CH_4 + 140.2\cdot C_2H_4 + 55.2\cdot H_2S,\ kcal/m^3;\ (1.1)$$

The Russian engineer NG Yudushkin [6] wrote in his work that this can be simplified in the case of thermal coal gas.

$$Q_l^{\,w} = 30.25\cdot CO + 25.27\cdot H_2 + 85.55\cdot CH_4,\ kcal/m^3,\ (1.2)$$

Where: CO, H_2, CH_4 - Volume content of each gas contained in the combustion gas,%;

30.25, 25.27, 85.55 – low heat value of CO and H_2, CH_4, kcal/m^3.

Results

These Shivee-Ovoo and Baganuur coal equations were used to construct linear and nonlinear regression function models, find optimal values for the coefficients of the equation, and test the reliability of the models with appropriate criteria. Based on this, the most reliable nonlinear models that can be used in the study were selected[7].

For Shivee-Ovoo coal, the above mathematical models are as follows.

$$Q=2051.6191+30.4067*P_i-0.0522*T_i-5.1032*G_{airi}-4.3736*G_{steami}-$$

$$-0.168*P_i*G_{airi}-0.28*P_i*G_{steami} \Rightarrow max \qquad (2.3)$$

$$CO = 40.5179 - 1.2726\cdot P_i - 0.09592\cdot G_{air_i} - 0.1925\cdot G_{steam_i} +$$
$$+0.00177\cdot P_i\cdot T_i - 0.00353\cdot P_i\cdot G_{air_i} > 0;$$
$$H_2 = 35.1231 - 0.5742\cdot P_i - 0.09138\cdot G_{air_i} + 0.000985\cdot P_i\cdot T_i -$$
$$-0.00404\cdot P_i\cdot G_{air_i} - 0.00507\cdot P_i\cdot G_{steam_i} > 0;$$
$$CH_4 = 0.5191 + 0.8781\cdot P_i - 0.000896\cdot P_i\cdot T_i + 0.000767\cdot P_i\cdot G_{air_i}$$
$$-0.00299\cdot P_i\cdot G_{steam_i} > 0;$$

Pressure, bar – 1<P<25, Temperature, ^{o}C – 500<T<1000,

Air flow, kg/h – 80 < G_{air} < 150 ,eam flow, kg/h –5 < G_{steam} < 30 (2.5)

The low heat value or purpose function of the combustible gas is given by 2.3, and the values of the combustible part of the gas component, CO, H_2, CH_4, and the separation zones are given by Equations 2.4 and 2.5.

In the above case, using nonlinear programming methods to calculate the optimization policy and determine the values of the parameters:

P*=10 bar, T*= 700 ^{o}C, Gair*=80 kg/h, Gsteam*=5 kg/h, CO= 28.7%, H_2 =25.5%, CH_4 =3.4% in the combustible gas composition and low heat value Q =1740 kcal/m^3.

Discussion

1. As a result of the research, non-linear regression mathematical models with high reliability were developed, which were tested by appropriate parameters to determine the composition of the combustible gas and its low heat value of Baganuur and Shivee-Ovoo lignite gasification processes.

Baganuur coal:

$$Q=2596.6565+85.1525*P_i+0.08064*T_i-6.2506*G_{airi}-$$
$$-0.01254*P_i*T_i-0.3091*P_i*G_{airi}-1.1334*P_i*G_{steami} \Rightarrow max$$

P*= 8 bar, T*= 700 ^{o}C, Gair*=100 kg/h, Gsteam*= 5 kg/h while CO=40.8%, H_2 = 23.16%, CH_4 =4.5% in the combustible gas composition, low heat value Q =2346.4 kcal/m^3,

Shivee-Ovoo coal:

$$Q=2051.6191+30.4067*P_i-0.0522*T_i-5.1032*G_{airi}-4.3736*G_{steami}-$$
$$-0.168*P_i*G_{airi}-0.28*P_i*G_{steami} \Rightarrow max$$

P*=10 bar, T*= 700 ^{o}C, Gair*= 80 kg/h, Gsteam*= 5 kg/h while CO=28.7%, H_2 = 25.5%, CH_4 =3.4% in the combustible gas composition and low heat value Q = 1740 kcal/m^3.

Conclusions

1. In our country, it is socially, economically and environmentally important to convert lignite into an energy-efficient combustible gas using steam-air blown, pressurized and easy-to-operate gas generators to replace imported liquid fuels.
2. According to the study, the gasification temperature of coal should be kept as low as 700-850 ° C and the pressure as high as 30 atm, and the amount of steam and air in the gasifying agent should be adjusted (steam/coal ratio 0.25, air/coal ratio 1- less) is more effective.
3. Suitable regimes for lignite gasification in some deposits of Mongolia are defined as gasification pressure of 10-15 bar, temperature of 700-900 ° C, blower airflow rate of 100-120 kg/h, and water vapor flow rate of 5-20 kg/h. In this range, Baganuur coal contains 30-45% carbon monoxide, 24-34% hydrogen, 7-15% methane, low heat value 2200-2800 kcal/m^3, and from Shivee-Ovoo coal containing 20-30% of carbon monoxide, 18-23% hydrogen and 1.5-7.5% methane, low heat value 1150-1600 kcal/m^3 it has been theoretically proven that it is possible to produce a combustible gas mixture.

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