Chen Ping, PhD, "Research on Principle and Industrial Application of Biomass Gasification in Fluidized Bed", Chinese Academy of Science, July 2006.

Abstract

As one kind of biomass thermo chemistry conversion technology, the aim of biomass gasification is attaining more possible combustible gas such as H2, CO, CH4 et al. due to the advantages of excellent gas-solid mixing, the uniform bed temperature, intensive mass and heat transfer and easy scale-up, fluidized bed gasifier was thought as the most promising reactor among all kinds of biomass gasifiers. At present, the main problems of biomass gasification in fluidized bed are the followings: the tar content in the product gas rather high and tar conversion or removal is very difficult; the product gas heating value is low when air was used as gasification agency; the scale-up rule of fluidized bed gasifier wasn't built up until now; the simulation results of modeling of biomass gasification in fluidized bed was poor. All the above problems have directly and significantly hindered the application of biomass gasification technology.

With a view to solve above problems, Funded by the National High Technology Research and Development Program of China (863 Program), the present study focused on the hydrodynamic characteristics of biomass particles in a cold fluidized bed and a cold circulating fluidized bed, the characteristics of biomass gasification in a lab-scale fluidized bed gasifier, tar high temperature cracking in a carbon furnace and the operation experiences of industrial biomass gasification and power generation systems.

The fluidization hydrodynamics of different biomass particles was firstly investigated at room temperature in different diameter fluidized bed in the thesis. The experimental results have shown: 1) The pure biomass particles such as sawdust /rice husk et al. can be fluidized. 2) The different biomass particles showed different fluidization characteristics. Sawdust is more easily achieved good fluidization than rice husk. when the gas velocity exceeded the complete fluidization velocity Ucf, bubbling fluidization was observed when sawdust was used as bed material, however channeling was often observed when rice husk was fluidized.3) the diameter of bed and the height of bed material has significant effects on fluidization quality. The wall effect wasn't ignored when the diameter of bed was less than 0.1 m, bigger diameter facilitates to improve fluidization quality. Slugging will be serious when H/D exceeds 3.0. 4) the experimental results of biomass particle in fast fluidization condition in a 0.28 m (ID) circulating fluidized bed shown that the 'core-annulus' flow structure of circulating fluidized bed was also observed. The profile of particle velocity at radial direction showed 'parabolic curve' shape, however the profile of voidage at radial direction was rather even. Changing the gas velocity and circulating flow rate Gs both had significant effects on the profile of velocity and voidage. 5) The experimental results of flow characteristics of biomass particles in Loop seal apparatus showed that, gas velocity in the riser has no effect on the circulating flow rate Gs; the Gs increase with the transport gas volume and auxiliary gas volume; the varying of auxiliary gas volume has more significant effects on Gs than that of transport gas volume; the modified equation from Wang's predicts the Gs in good agreement with the experimental data.

The characteristics of sawdust gasification in a 0.3×0.3m lab-scale fluidzed bed was investigated.

As the experimental results shown, when ER=0.23~0.38, the gasifier temperature: 689~820℃，the tar content in product gas: 34.45~92.47g/Nm3, the heating value of cold dry product gas: 5650~6765kJ/Nm3, the gas productivity: 1.5~2.2Nm3/kg, carbon conversion efficiency: 68.8~96.5%, gasification efficiency: 57.9~85.3% are achieved. The experimental results of tar high temperature cracking in a carbon fixed bed have shown that the ratio of tar cracking increases with the cracking temperature ascending. When the cracking temperature is above 1050℃, the ratio of tar cracking exceeds 92%. The comparison of tar composition and product gas composition before/after cracking showed that: after cracking, the aromatic hydrocarbon increases, however the polar component decreases; the content of H_2 in the product gas significantly increases, however the content of CH_4, C_2H_2, C_2H_4 and C_2H_6 decreases more and less. The heating values of product gas decreases about 20%, but still reach 5MJ/Nm3, which still are enough for engine

The operation performance of a MW-scale rice husk gasification and power generation plant built in Chanxinging city, Zhejiang province, China was also tested. As the test results shown: due to the fluidization velocity not enough high, the mixing of dense region wasn’t ideal which easily caused the bed temperature exceed the ash fusing point at some spot of the gasifier so as to the whole gasifier agglomeration. The bed temperature linearly rose up as ER increasing. The heating value of product gas decreasing with bed temperature rising up, however the load varying seems to have no effect on it. The gas productivity, carbon conversion efficiency and gasification efficiency improved as ER and load increasing. The moisture content of rice husk also has great effect on the operation performance of gasifier, when the moisture content exceeds 15%, the bed temperature will severely fluctuate. The ash by rice husk gasification can be used as insulating materials, cement additive and potassium fertilizer et al.

The first biomass integrated gasification combined cycle demonstration plant built in xinhua city, Zhejiang province, China, which was also the biggest power plant used biomass as materials at the present, was introduced and primarily tested. The successful operation of demonstration plant proves the technology route of biomass gasification-engine-steam turbine combined cycle is feasible. The primary test results of 20MWth biomass circulating fluidized bed gasifier showed: the heating value of product gas reached 5680-6218kJ/Nm3 when the bed temperature was 700~800 ℃. Under 50% load and ER=0.22~0.35, the maximum carbon conversion efficiency was up to 90% and gasification efficiency was up to 80%. Comparison with the test results of 800 kW rice husk gasification and power generation plant, the fluidized bed gasifier scale up from 5MWt to 20MWt, the heating value of product gas didn’t decrease however increased a little. The test results of 450kW gas engine modified by 8300 oil engine, which was the biggest power engine using the low heating value product gas as fuel in China, was shown that the power efficiency of engine reached 28.8~29.7% when the load was 70-90% and improved 16% than the 200 kW engine.

Finally, using the data of three different scale gasifiers, a prediction model Based on artificial neural network was proposed to predict the characteristics of biomass gasification in fluidized bed. Three models for individual gasifier, in which the material feeding rate and air volume was treated as input variables, the bed temperature, the heating value of product gas, gas productivity, carbon conversion efficiency and gasification efficiency were treated as output variables, showed good prediction ability. However the combined model adding the gasifier diameter as input variable showed a little poor prediction ability.