Water Vapor and Latent Heat Recovery From Biomass Boiler

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Abstract

To discuss the feasibility of recovering condensate water and latent heat from biomass boiler, the volume fraction of water vapor in flue gas after combustion of various biomass under different conditions was compared by means of theoretical calculation, and the actual verification is carried out on a biomass gasification combustion test bench. The theoretical calculation shows that when the biomass gasification is used, the content of water vapor in the flue gas can be as high as 20%. In some cases, it is even more than the content of steam in the gas burning flue gas, which shows that the recovery of water vapor and its latent heat in the biomass burning flue gas is completely feasible.

Keywords

Biomass boiler; thermal efficiency; condenser.

1. Introduction

Continuous haze weather has a serious impact on people's lives and health. In order to improve environmental problems, China has forced the elimination of small coal-fired industrial boilers and started to vigorously promote natural gas boilers. However, China's energy consumption is growing at a rate of 6% to 7% every year, and the energy situation is getting tighter and tighter[1]. Comparatively speaking, biomass has the advantages of renewable, low pollution, wide sources, low ash and sulfur content, and carbon neutrality. The development and utilization of biomass energy has attracted wide attention of the international community [2-4]. In Europe, especially in the Nordic countries such as Finland, Sweden and Norway, these countries have abundant forest resources. The biomass boilers using sawdust as raw materials have a perfect technical system, and have begun to try to apply condensing boiler technology to biomass boilers. However, the research of biomass boilers in China is still in its infancy [5,6]. In this paper, the recovery of condensate water from flue gas of coal with higher moisture content, H/C ratio and O content of biomass fuel is studied.

2. Feasibility of Recovering Steam and Latent Heat from Flue Gas By Biomass Boilers

Biomass fuels usually contain more water than fossil fuels such as coal, petroleum and natural gas. If the content of water vapor in flue gas is higher after biomass combustion, the latent heat of water vapor recoverable in exhaust flue gas will be large. In a certain range, the smaller the excess air coefficient, the higher the recovery rate of waste heat and the lower the heat loss of exhaust gas. The basic properties of biomass fuels are shown in Table 1. The reaction formulas of pine, Enteromorpha clathrata, rice straw and air are shown in Formula (1) - (3) respectively. At the same time, through calculation, the volume percentage of water vapor in flue gas of pine,

Enteromorpha clathrata and rice straw with different moisture content and excess air coefficient was obtained, respectively, as shown in Fig.1-3.

Table 1. Proximate and ultimate analysis of feedstock

category	Industrial analysis/%				elemental analysis /%				
	Mad	FCad	Vad	Aad	Cad	Had	Oad	Nad	Sad
pine	10.14	35.96	50.3	3.6	41.8	5.78	37.8	0.8	0.08
Enteromorpha clathrata	13.30	7.79	41.82	37.09	22.74	6.27	16.19	3.14	1.27
Rice straw	5.25	17.66	66.37	10.72	23.64	4.77	54.13	1.43	0.08

$$CH_{1.5}O_{0.7}+1.025O_2+(1.025\times0.79/0.21)N_2=CO_2+0.75H_2O+3.856N_2 \quad (1)$$

$$CH_{3.3}O_{0.5}+1.075O_2+(1.075\times0.79/0.21)N_2=CO_2+1.65H_2O+4.044N_2 \quad (2)$$

$$CH_{2.4}O_{1.7}+0.755O_2+(0.75\times0.79/0.21)N_2=CO_2+1.2H_2O+2.821N_2 \quad (3)$$

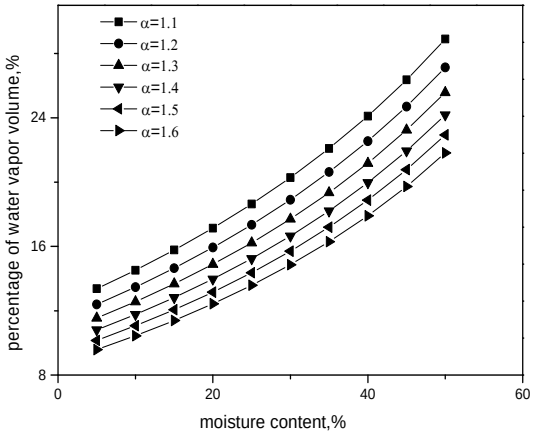

Fig 1. Relationship between moisture content of pine wood, excess air coefficient and volume fraction of water vapor

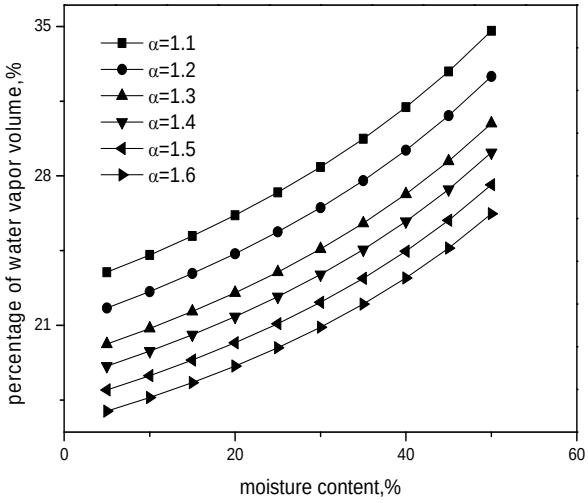

Fig 2. Relationship between moisture content of enteromorpha clathrata, excess air coefficient and volume fraction of water vapor

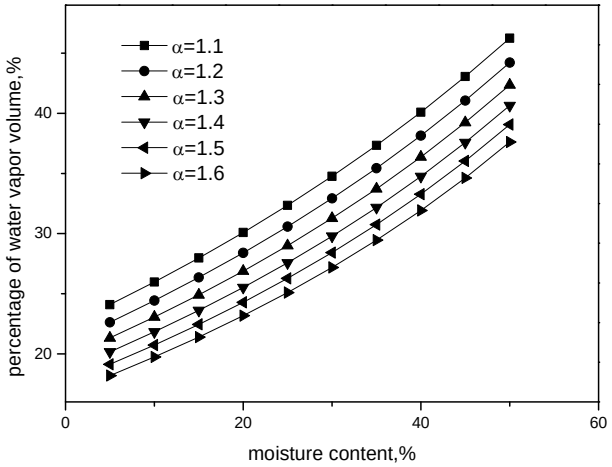

Fig 3. Relationship between moisture content of rice straw, excess air coefficient and volume fraction of water vapor

It can be seen from Fig.1-3 that under the same excess air coefficient, with the increase of moisture content of biomass fuels, the volume content of water vapor in flue gas tends to increase, while with the same moisture content of biomass, the content of water vapor in flue gas decreases with the increase of excess air coefficient. Taking water content of 15% and excess air coefficient a=1.1 as examples, the volume of water vapor in flue gas after pine burning accounts for about 17%, that of Enteromorpha striata burning for about 25%, and that of rice straw burning for about 28%. From the calculation results, it can be seen that under certain conditions, the condensation heat of water vapor in flue gas can be recovered and the heat loss of exhaust gas can be reduced, so as to improve the energy utilization rate, and the rice straw with the highest volume content of water vapor is particularly suitable as biomass fuel.Compared with coal and natural gas as fossil fuels, biomass fuels have more advantages in recovering waste heat and improving the thermal efficiency of boilers.

3. Conclusion

According to the elemental analysis and industrial analysis of three different biomass, the excess air coefficient (a=1.1) was calculated. For example, the volume of water vapor in the flue gas after pine burning accounted for about 17%, that of Enteromorpha striata burning accounted for about 25%, and that of rice straw burning accounted for about 28%. Therefore, biomass boilers have great potential to recover steam and latent heat from flue gas.

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