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Analysis of the Effect of Water Ash Ratio on the Efficiency of Domestic Waste Incineration Power Generation

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Abstract

With the continuous development of our society and the acceleration of the urbanization process, the continuous improvement of the living standards of residents, the total amount of domestic waste has also increased, resulting in a series of problems. The report of the 19th National Congress highlighted the importance of ecological civilization, and included "strengthening the construction of ecological civilization" as a five-year development goal in the 13th Five Year Plan. Currently, there is a problem of low efficiency in the recycling of urban domestic waste in China. This paper analyzes and studies the impact of moisture content and high ash content on waste recycling during the process of waste utilization. Finally, relevant countermeasures are proposed based on relevant issues.

Keywords

Domestic Garbage; Incineration Power Generation; Water Cement Ratio; Impact Analysis.

1. Introduction

With the continuous advancement of urbanization in China, a large amount of urban domestic waste is generated every day. How to shift domestic waste from simple harmless digestion and treatment to active utilization as a resource, and achieve the economic track of recycling and utilizing waste as a resource and energy is one of the important aspects of achieving sustainable urban development [1]. Domestic waste recycling can achieve the goals of saving natural resources, protecting the environment, and reducing pollution, while achieving a unified win-win situation of economic, environmental, and social benefits [2]. Currently, the main treatment methods for urban domestic waste in China include sanitary landfill, composting, and incineration for power generation [3-4]. However, with the continuous development of the economy, the increase in domestic waste is accelerating, land resources are increasingly scarce, and the non-decomposable components in domestic waste are increasing. Sanitary landfill treatment is no longer suitable for the development of today's society [5]. In order to achieve harmless treatment, reduction, and resource utilization of urban domestic waste, thermochemical treatment can be an effective way to achieve rapid decomposition and resource utilization of domestic waste [6].

In the process of resource utilization, the relative ratio of domestic waste to fossil energy has problems such as high moisture and ash content, low calorific value, and complex composition, which are important factors affecting the process of domestic waste resource treatment [7-8]. In developed countries, the vast majority of waste recycling is conducted through classified collection, resulting in a low water content (typically between 5% and 25%). In China, the water content of domestic waste is basically within the range of 40% - 60%, and a small amount of kitchen waste has a water content exceeding 60%. Therefore, the calorific value of waste is low, and the economic benefits of heat

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treatment are not obvious. At the same time, the ash content also has a significant impact on the calorific value of waste. Low calorific value of waste will affect the stability of heat treatment, so the low calorific value of waste entering the incinerator should not be lower than 5000 kJ/kg, and the incineration flue gas should last for more than 2 seconds at an ambient temperature of 850 ℃. Currently, due to the high-water content and ash content of raw waste, the combustion temperature will be lowered, and the heat loss of exhaust gas will be increased. The incineration utilization rate is very low, and the stability of the treatment process will also be greatly affected [9-10]. This paper mainly studies the effects of water content and ash layer on calorific value, smoke discharge, and power generation, providing relevant theoretical basis for waste heat treatment.

2. Effect of Water Cement Ratio on Calorific Value of Waste

2.1 Effect of Water Content on Calorific Value of Waste

The water content in garbage is not only affected by geographical factors, but also by factors such as season, weather, and temperature. The change in water content has a significant impact on the calorific value of garbage. the detection status of domestic waste in a certain place in Lhasa is shown in Table 1:

Table 1. Industrial analysis and elemental analysis of domestic waste

Project	C_{ar}	H_{ar}	O_{ar}	N_{ar}	S_{ar}	Cl_{ar}	M_{ar}	A_{ar}	Total	$Q_{net,ar}$ (kJ/kg)
Content	18.6%	2.9%	14.5%	0.1%	0.1%	0.05%	52.6%	11.2%	100%	5591.4

The theoretical calculated calorific value is approximately 6407 kJ/kg, which has some error compared to the actual value detection data. Therefore, in this article, the detection data $Q_{net,ar}$=5591.4kJ/kg is used as the benchmark for analysis and calculation.

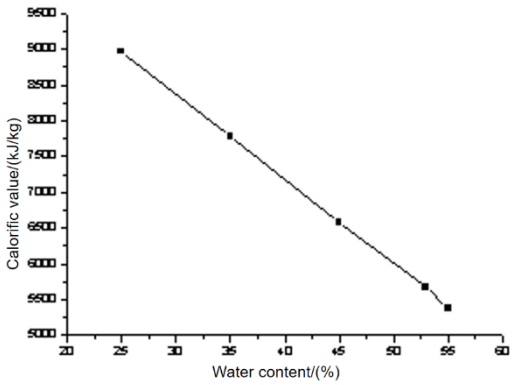

Fig 1. Effect of Moisture Content on Garbage Calorific Value

As can be seen from Figure 1, when the ash content is 10%, the calorific value of garbage will gradually decrease with the increase of water content; When the moisture content is about 25%, the calorific value of garbage is as high as about 9000 kJ/kg; When the moisture content increases to 55%, the calorific value of garbage will rapidly decrease to 5380 kJ/kg. This is due to the fact that during the energy conversion process of garbage, the amount of garbage per unit mass will increase as the moisture content increases, and the combustible components with higher calorific value per unit mass of garbage will decrease, resulting in a lower calorific value per unit mass of garbage with higher moisture content.

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2.2 Impact of Dust on Calorific Value of Garbage

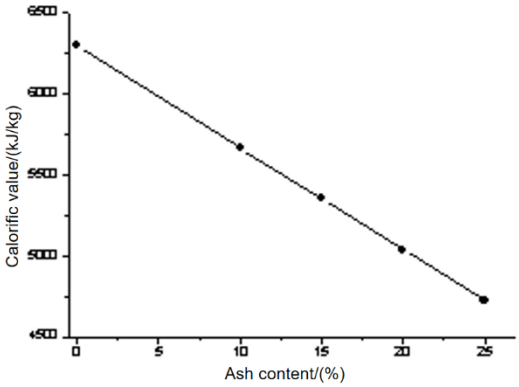

Fig 2. Effect of Ash Content on Garbage Calorific Value

As can be seen from Figure 2, due to the presence of dust in the waste, the combustible components in the unit mass of waste will decrease, and the unit calorific value of waste will change. With the increase of ash content in raw waste, the calorific value in waste decreases linearly. When the ash content is 25%, the calorific value of raw waste is 4722 kJ/kg; When the ash content is 10%, the calorific value of raw waste is 5666kJ/kg, which decreases by about 20%. Therefore, it can be seen that dust also has a significant impact on the calorific value of waste.

3. Effect of Water Cement Ratio on Gas Content in Waste

3.1 Impact of Water Content on Gas Content in Waste

In the process of recycling waste energy, due to the complex composition and structure of waste, there is a large amount of oxygen required during the incineration process. Therefore, the water content in waste has a significant impact on the air demand during waste incineration. Through experimental analysis, detection, and integration of relevant data, it can be seen that the higher the moisture content of garbage, the less air required during garbage combustion. This is mainly due to the early evaporation and release of water as the volatile matter of garbage during the process before garbage combustion, while the combustion process is mainly due to the need for air for the combustibles in garbage. However, in waste with high water content, the content of combustibles is relatively low, resulting in a low amount of air required for combustion of waste with high water content. According to calculation, when the water content is 25%, the unit volume of waste combustion requires about 5000m ^{3} air When the water content is 55%, the unit volume of waste combustion requires about 3000m ^{3} air the difference from 25% moisture content of garbage is about 60%. As can be seen from Figure 3, water content has a significant impact on waste heat treatment, so reducing water content has high practical significance for waste energy treatment.

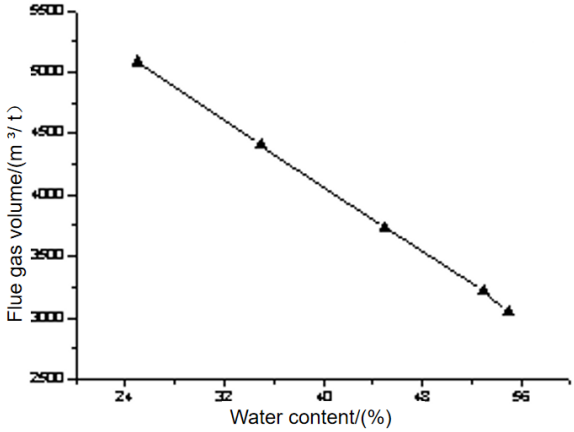

Fig 3. Effect of water content on gas content in waste incineration

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At the same time, the content of water in garbage has a significant impact on the thermal utilization of garbage, which is greatly reflected in the demand for air during the combustion process of garbage. The amount of flue gas generated by the combustion of combustibles in garbage is due to the oxidation reaction between oxygen and nitrogen in the air and combustible components of garbage to produce gases such as carbon dioxide, sulfur dioxide, and nitrogen oxides. The air content has a positive proportional impact on the content of flue gas after garbage thermal treatment, At the same time, the percentage of combustible components in garbage determines the amount of air used, while the content of combustible components in garbage determines the amount of flue gas. The combustible components of garbage are affected by the moisture content in garbage, which plays an important role in the amount of flue gas generated by garbage thermal utilization. With the increase of water content, the flue gas output per unit mass of garbage combustibles will decrease. When the moisture content is 25%, the amount of flue gas in the waste is about 6500m^3/t; At a water content of 55%, the flue gas output is about 3900 m^3/t. Therefore, water content plays a crucial role in the treatment of garbage.

3.2 Impact of Dust on Air Content in Garbage

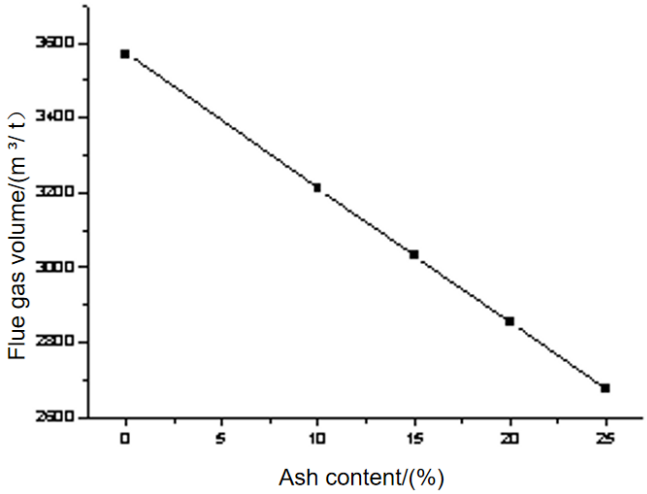

Fig 4. Impact of Ash Content on Gas Content in Waste Incineration

From the above analysis, it can be seen that moisture has a significant impact on garbage, but in real life, the ash and soil content in garbage also has a certain impact on garbage treatment in different regions. From Figure 4, it can be seen that when the ash content is 25%, the unit volume of garbage treatment requires about 2677m^3 Air: As the ash content decreases, the amount of air required for waste heat treatment increases. When the ash content is 10%, the amount of air required for incineration is 3200m^3, the amount of air required per unit mass of garbage has increased by 20%, and it can be seen from the above that the ash content has a significant impact on the amount of air during the combustion of garbage combustibles.

Although the impact of ash content on waste is relatively small compared to water content, its overall impact on waste treatment is still large. When the ash content of raw waste is 25% during the combustion process, the amount of smoke produced per ton of waste is 3400m^3/t. When the ash content decreases to 10%, the amount of smoke produced per ton of garbage is 4110m^3/t., the gas production increased by 22%.

4. Impact of Water Cement Ratio on Power Generation

4.1 Impact of Water on Power Generation

In the process of garbage recycling, turning domestic solid waste into the most widely used electrical energy through thermal energy utilization has high value for garbage recycling. The reuse of domestic waste not only realizes the energy utilization of resources, but also reduces the environmental pollution caused by solid waste. There are still many problems in the process of converting waste

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resources into electricity. Moisture content not only affects the combustion of waste during incineration, so waste must undergo mechanical sorting, manual sorting, preheating, and drying before incineration for power generation. This mainly refers to food, vegetables, fruit peels, branches and leaves in perishable wet garbage. In their dry basis state, the calorific value is very high, which is 10380kJ/kg, 13510kJ/kg, 14906kJ/kg, 15908kJ/kg, respectively. When burning raw waste, it cannot be directly burned due to its high moisture content, and the proportion of perishable waste in domestic waste is about 56%. The moisture content of each component of perishable waste is between 60% and 90%. According to the data in Figure 5, with the increase of moisture content, the power generation capacity per unit mass of waste gradually decreases. When the moisture content of raw waste is 55%, each ton of waste can generate 328.78kW • h of electricity; When the water content is 25%, each ton of garbage can generate 547.96kW • h of electricity, increasing the power generation rate by 66.67%; The raw untreated waste can generate 346.3kW • h of electricity per ton, which has a significant impact on waste power generation.

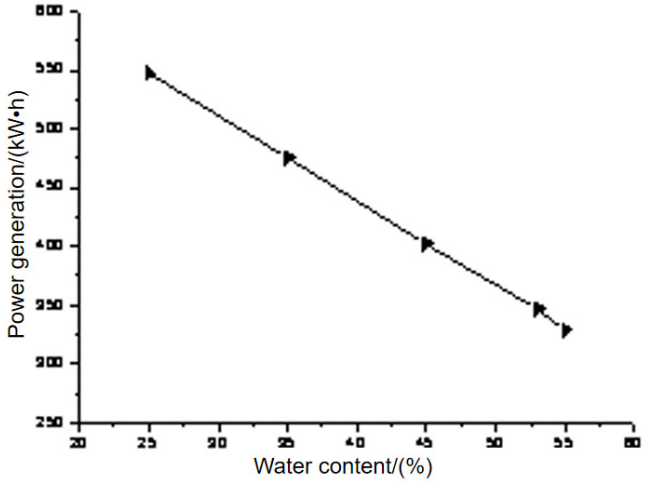

Fig 5. Impact of water content on garbage power generation

4.2 Impact of Dust on Power Generation

The power generation capacity of domestic waste is not only affected by the water content, but also by the ash content. The heat generation capacity of dust during combustion is very low. Due to the increase in ash content per unit mass of garbage, its combustible components are relatively reduced, and the calorific value of garbage will decrease. At the same time, due to the recycling process, the dust in the garbage is converted into slag, fly ash, etc., which will take away more heat, thereby reducing the power generation efficiency of the garbage. As shown in Figure 6, when the ash content of raw waste is 25%, the power generation capacity per unit mass of waste is 288.59kW • h/t; With the decrease of ash content, at a 10% ash content, its power generation increased by about 20% to about 346.31 kW • h/t.

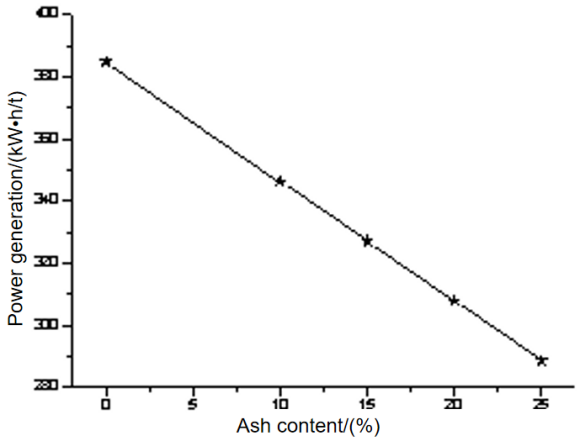

Fig 6. Impact of ash content on garbage power generation

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5. Conclusion

(a) The increase in the moisture content of domestic waste will reduce the calorific value of the waste. During the incineration heat treatment process, due to the need for evaporation and precipitation of water, a large amount of latent heat of vaporization will be brought out, resulting in significant energy losses for the thermal utilization of waste incineration, leading to reduced power generation efficiency. At the same time, it will also reduce the temperature of the bed layer, which is not conducive to the incineration process. Due to the large amount of water contained in the flue gas, it will also have a significant impact on the back-end flue gas treatment and equipment corrosion, reducing the service life of the equipment.

(b) As the ash content of domestic waste increases, the calorific value of the waste will decrease, and the thermal utilization of waste incineration will decrease. During the thermal treatment and incineration process, the ash content in the tail gas will increase, while reducing the power generation efficiency, resulting in a significant decrease in the economy of waste treatment.

It can be seen from the above that adopting different classifications for domestic waste can not only reduce the moisture content of the waste, but also reduce the amount of ash entering, while improving the calorific value of the combustible components in the waste; It has a significant impact on improving waste treatment efficiency, increasing power generation, and promoting efficient and long-term stable operation of the waste incineration process; Therefore, the ultra-high pressure mechanical classification treatment at the front end of garbage, the classification treatment of residents at the source of garbage, or the classification treatment combining manual sorting and mechanical screening, has far-reaching practical significance for the harmless, reduction, and resource utilization of urban domestic garbage.

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