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A Study of Solid-liquid Separation Equipment Based on Kitchen Waste Treatment

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Abstract: The amount of kitchen waste generated in China has been high in recent years. Kitchen waste contains very high levels of moisture and organic matter and is highly perishable and odorous. There are a lot of ways to dispose of kitchen waste, such as burial and incineration. However, the use of inappropriate disposal methods can be harmful to the environment and even to human life. This is why the paper discusses a study of an energy efficient and environmentally friendly solid-liquid separator that separates kitchen waste into solids and liquids and enables the separation of biogas.

Keywords: The disposal of kitchen waste; Energy saving; Solid-liquid separation.

1. Introduction

In the past ten years, with the rapid development of China's catering industry, the production of kitchen waste, a by-product, has increased year by year. By 2021, China's kitchen waste production has reached 127 million tons, an increase of 5.8% compared with 2020, and nearly 6% per year for more than ten years. The treatment and reuse of kitchen waste has also become an urgent problem to be solved in recent years. The traditional treatment methods include landfill, incineration, etc., but these exist to pollute the environment, consume public resources, endanger public safety and a series of problems. Therefore, the solid-liquid separation equipment is particularly important for the treatment of kitchen waste, so how to achieve a more efficient and energy-saving solid-liquid separation equipment will be an urgent problem to be solved. Based on this, several common solid-liquid separation equipment on the market today are understood by querying the data, and their advantages and disadvantages are analyzed. After comprehensive consideration, a more energy-saving and environmentally friendly solid-liquid separation equipment for treating kitchen waste is proposed.

2. Current situation of kitchen waste treatment in China

The current technical status of food waste is divided into biotechnology and non-biological technology. The use of solid-liquid separation equipment is a kind of non-biological technology. The treatment of kitchen waste in various parts of China is mainly an operation mode of 'collection-transportation-treatment'. The treatment project is mainly based on the purchase service mode. The common treatment methods include 'Build Operation Transfer' (BOT), 'Build Operation Ownership' (BOO), 'Engineering Procurement Construction' (EPC) and 'Public Private Partnership' (PPP), although the PPP model has gradually become the mainstream, the BOT model is still the main operation mode [1]. However, on the whole, the treatment of kitchen waste in China is not optimistic. The scale of treatment is in the initial stage of development, and the comprehensive utilization rate is not high. According to the "14th Five-Year Plan for the Development of Urban Domestic Waste Classification and Treatment Facilities" to the end of 2025, the comprehensive utilization rate of kitchen waste should reach more than 60%. Therefore, in recent years, the newly-raised food waste treatment projects in China have been growing rapidly, and solid-liquid separation equipment is a new type of non-biological technology treatment.

3. Research status of solid-liquid separator

At present, there are several common solid-liquid separation equipment:

(1) Plate and frame filter press

Through the plate and frame extrusion, the liquid in the garbage is sent out through the filter cloth, and the dry garbage is accumulated on the filter cloth, so as to realize the solid-liquid separation. The advantages of the equipment are simple structure, easy operation, long equipment life, and high solid-liquid separation efficiency. Due to the accumulation of dry waste on the filter cloth, the filter cloth is easy to block and needs to be replaced frequently, making it impossible to work continuously for a long time, and not suitable for oily waste.

(2) Belt dehydrator

The belt dehydrator is composed of filter belt, rolling cylinder, filter belt tensioning system, filter belt deviation adjustment system, filter belt drive system and filter belt washing system. After the kitchen waste flows into the upper and lower strip filter cloths that rotate continuously between the rollers, the tension of the filter cloth and the pressure and sheer force of the roller act on the garbage sandwiched between the two filter cloths in turn for gravity concentration and pressurized dehydration. The dehydrated dry garbage is stripped by the scraper, and the filter cloth after stripping the dry garbage is cleaned with water to prevent the filter cloth hole from clogging and affect the filtration speed [2].

(3) Centrifugal dehydrator

In the centrifugal dehydrator, the centrifugal force generated by high-speed rotation causes the garbage particles with a large proportion to be thrown to the inner wall of the drum to form a solid layer, and the water with a small

centrifugal force forms a liquid layer inside the solid layer to achieve solid-liquid separation. The equipment occupies a small area and has a high degree of automation. It is suitable for large sewage treatment plants, but it also has the disadvantages of high energy consumption, high noise and high maintenance technical requirements.

(4) Ceramic filter

The microporous ceramic is used as the filtration medium, and the solid-liquid separation equipment is designed by using the principle of capillary action of a large number of narrow microporous ceramics. In the disc filter under negative pressure working condition, the unique permeability and impermeability of the microporous ceramic plate are used to extract the pressure difference generated by the vacuum of the inner cavity of the ceramic plate from the outside, so that the suspended materials in the material tank are adsorbed on the ceramic plate under the action of negative pressure. The solid material cannot be retained on the surface of the ceramic plate through the microporous ceramic plate, and the liquid is successfully discharged into the gas-liquid distribution device due to the vacuum pressure difference and the hydrophilicity of the ceramic plate [3]. Because the main body of the equipment is made of ceramics, it has certain strength, wear resistance and corrosion resistance, and the service life is relatively long, but the micropores are easy to cause blockage and affect the work efficiency.

(5) Screw dehydrator

The main body of the dehydrator is mainly composed of a filter body and a spiral shaft. The filter body has two parts: a concentration part and a dehydration part. When the garbage enters the filter body, the relative movement of the fixed ring and the moving ring is used to make the filtrate pass through the laminated gap. The filtrate is quickly discharged outwards and quickly concentrated, and the garbage is moved to the dehydration part. When the sewage sludge enters the dehydration part, the space in the rate chamber is continuously reduced, and the internal pressure of the garbage is continuously enhanced. Coupled with the back pressure of the pressure regulator at the mud outlet, it achieves the purpose of efficient dehydration, and the garbage is continuously discharged outside the machine [4]. This device is suitable for oily waste, with a high degree of automation, complete functions, and a small footprint. However, because of its small volume, it is not suitable for handling large particle waste and the workload is not large.

(6) Drum filter

The rotary drum solid-liquid separation equipment is a rotary drum screen filter device. The treated wastewater enters the drum along the axial direction and flows out radially through the screen. The impurities in the water (fine suspended solids, fibers, pulp, etc.) are trapped inside the filter on the drum. When the impurities trapped on the filter are brought to the upper part by the drum, they are backwashed by the pressure flushing water and flow out into the slag discharge tank [5]. It has strong ability to deal with floating garbage, small footprint, convenient operation and manpower saving. But the financial requirements are too high and not conducive to the filtration of high temperature suspension.

Comprehensive analysis of the above six solid-liquid separation equipment can be found that there are some problems such as unsustainable treatment, low work efficiency, and easy blockage. Therefore, a new type of solid-liquid separation equipment that can better solve these problems is needed to meet the needs of the market for kitchen waste treatment.

4. Project research objectives and main content

4.1. Research objectives

Design a device that can achieve solid-liquid separation well, and can better collect the separated gas and send it to biogas fermentation to achieve resource reuse, reduce environmental pollution, increase the development rate of new energy, and avoid most of the existing shortcomings of solid-liquid separation equipment commonly used on the market.

4.2. Main research contents

A more practical overall structure of solid-liquid separation equipment is designed. Compared with the existing equipment, the higher solid-liquid treatment efficiency is determined by testing different parameters. For the design of the shifting part, the rotor part can achieve multiple continuous solid-liquid separation based on the ‘Venturi effect’, and at the same time achieve a relatively high dehydration rate for solid-liquid mixed waste.

4.2.1. Technical route

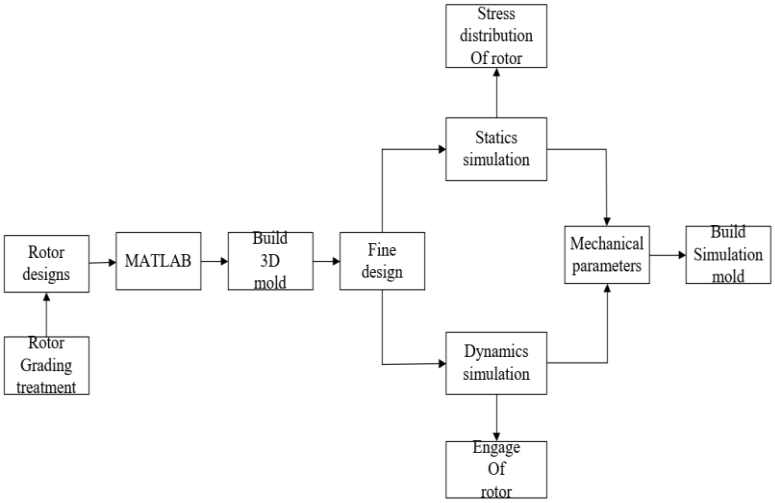

Fig.1 Technical route

As shown in the above diagram (Fig,1), before constructing the overall model, it is necessary to construct a more suitable

dial rotor model. After the design of the dial rotor meets the requirements (that is, it can be better fitted during the action process and the stress distribution of each rotor is more uniform and reasonable at work), the static simulation and dynamic simulation are carried out according to other parameter values. After obtaining the key parameters, the overall structure of the solid-liquid separation equipment is designed.

4.2.2. Design of dial rotor

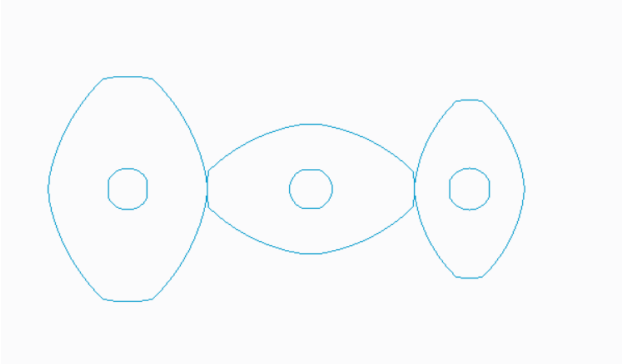

Fig.2 The dial material rotor

The dial material rotor (Fig.2) is the core component of the solid-liquid separation equipment mentioned in this paper. The whole structure is stacked by three elliptical slices. The elliptical slices are driven by the motor to move in the same rotation direction. When the dial material unit is seamlessly engaged, the liquid will flow through the gap between the elliptical slices to the liquid treatment box below the solid-liquid separator. The solid part is left above the elliptical slice and moves forward through the rotor. Under the effect of 'Venturi' effect, the rotation direction of the motor is moved to the back end of the rotation. Therefore, it is very important for the design of the dial rotor to ensure that the units can achieve seamless meshing. The meshing degree between the rotors directly determines the solid-liquid separation efficiency of the equipment. For the design of contour parameters, MATLAB design algorithm is needed. In this algorithm, the initial parameter value is set to solve the shape parameters of the dial-up rotor unit, and then the size model of the dial-up unit is established by parametric design. After obtaining the size parameters, the three-dimensional model of the rotor unit is constructed in the modeling software. Finally, the motion simulation is carried out to simulate the actual running state and detect whether there is interference.

4.2.3. Overall structure design of solid-liquid separation equipment

On the basis of completing the simulation of the core component dial rotor and confirming the feasibility, the overall structural design of the equipment is carried out. The main design contents include the feed inlet of the solid-liquid separation device, the solid separation outlet, the liquid separation outlet and the gear transmission mechanism. Structural optimization design of solid-liquid separation equipment: In order to improve the efficiency of solid-liquid separation of kitchen waste as the optimization goal, by setting the factors affecting the separation efficiency as the variable parameter quantity, the correlation function of the calculation model of the solid-liquid separation processing capacity is established. After continuous testing of the variable parameter data, the objective function is maximized, and the highest processing efficiency of the design can be obtained in theory.

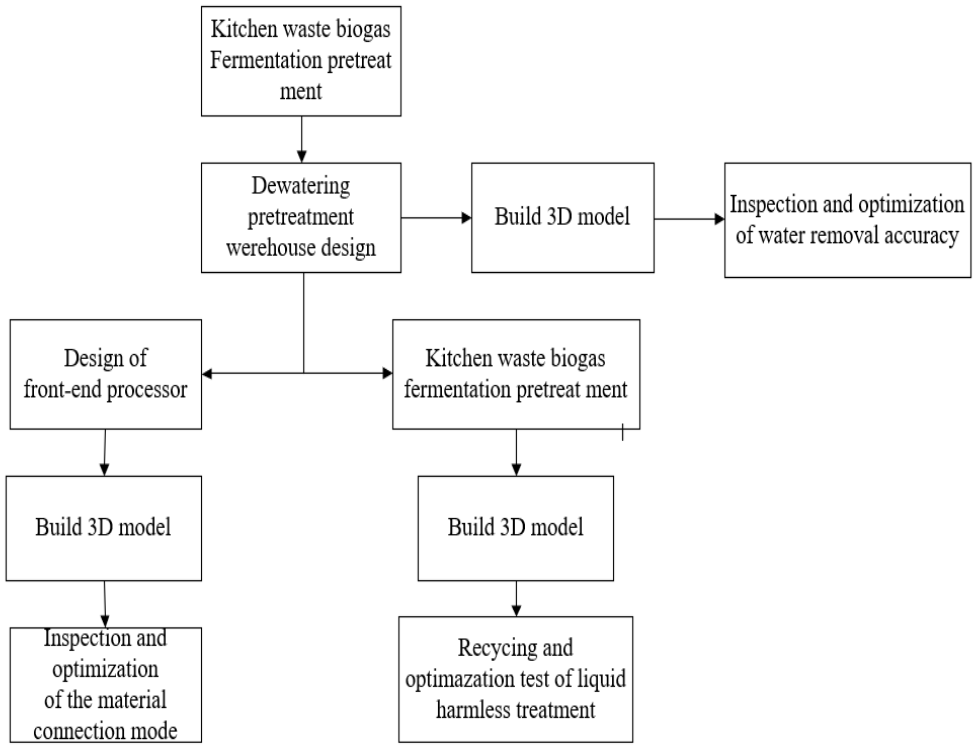

Fig.3 The main work flow

According to the main work flow (Fig.3), the inlet port adopts a fine mesh structure. When the solid-liquid mixed garbage is fed, the water removal pretreatment will be carried out in the inlet channel. The smaller mesh structure enables the suspended liquid in the mixture to enter the liquid treatment box and separate the larger particles. This part can be washed by a small amount of water to prevent smaller particles from blocking the fine mesh. The remaining part of

the garbage enters the front-end collector for further solid-liquid separation through the dial rotor unit. The solid garbage moves forward with the rotor through the meshing of the dial rotor, and the liquid separation flows through the rotating meshing of the rotor into the liquid treatment box. After the action of several rotors, a more efficient solid-liquid separation can be achieved, and the separated solid waste is sent to the solid treatment device. After the completion of the whole treatment project, the collected solid-liquid separation is harmlessly treated. The solid waste can be sent to incineration power generation, composting and other uses. The liquid can be recycled, such as sent to biogas power generation to increase the development rate of new energy. By working with other devices such as feeding devices, product collection devices, product processing devices, etc., continuous and efficient work can be achieved, and the degree of automation is high, and the manpower requirements are low. Therefore, the high efficiency treatment process of energy saving and environmental protection is better realized.

After the establishment of the three-dimensional model of each component in the equipment is completed, the corresponding simulation test is required to meet the standard. The static model of the solid-liquid separator is established in ANSYS software, and the static simulation of the solid-liquid separator is carried out. The stress analysis, stiffness, strength calculation and drive motor selection of the gear transmission device are carried out. After all parts are debugged, the whole mechanism after assembly is processed and debugged. After all qualified, the equipment can be put into production. The following figure is the three-dimensional model of the overall structure of the solid-liquid separation equipment (Fig.4) described in this paper.

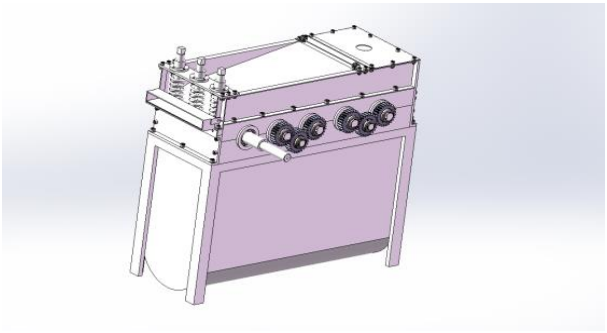

Fig.4 Three-dimensional model of the overall structure of the equipment

5. Conclusion

In mining, metal smelting, chemical engineering. In environmental protection, biotechnology and other industries, solid-liquid separation technology is an indispensable process. Even if it is not a manufacturing industry in many of the above industries, because it is ultimately a solid, and its corresponding production process needs to be carried out in a liquid environment, solid-liquid separation technology is needed [6]. Although there is still a certain gap between China's solid-liquid separation level and that of foreign countries, in recent years, China has vigorously supported solid-liquid separation equipment, especially after the proposal of the '14th Five-Year Plan for the Development of Urban Domestic Waste Classification and Treatment Facilities'. However, China is a large catering country. The annual output of kitchen waste is a huge number. The traditional treatment methods begin to show fatigue and are difficult to meet the treatment requirements. As an emerging treatment method, solid-liquid separation equipment needs to be continuously innovated and developed to achieve more efficient and environmentally friendly equipment.

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