Journal of Innovation and Development
ISSN: 2958-4752 | Vol. 11, No. 2, 2025

Tobacco Wastewater Treatment Plant Based on Magnetic Seed Flocculation Technology

Shang Li*, Jianghai Deng

School of Mechanical and Electrical Engineering, Wuhan University of Technology, Wuhan, China
*Corresponding author: 2911001572@qq.com

Abstract: The project is a tobacco wastewater treatment device, which mainly includes a magnetic seed dropping pump, a micro-flocculation chamber, a special media roller adsorption device, a micro-jetting device, a magnetic seed recovery device, and a separation device. Tilted baffles are used to convectively fuse wastewater, flocculant, coagulant aid, and magnetic seeds to improve flocculation efficiency under gravity and magnetic force; a special arrangement of disk structure is used to recover flocculant; and a water jetting device is used instead of disk blades to improve the recovery rate of magnetic seeds. This device combines several devices to realize effective treatment and recovery of tobacco wastewater, and applies the super magnetic separation technology to solve the problems of large footprint, low efficiency of wastewater treatment, and waste of magnetic seeds in the traditional method.

Keywords: Wastewater Treatment, Tobacco Wastewater, Energy Conservation.

1. Introduction

1.1. Research background of works

In recent years, the country has increased its efforts in wastewater treatment, and tobacco wastewater accounts for a relatively large proportion of total wastewater discharge, with emissions rising year by year. To reduce the pollution of tobacco wastewater to the environment, designing a new and efficient tobacco wastewater treatment device is of great significance.[1] This device combines multiple components not only to achieve effective treatment and recovery of tobacco wastewater but also to address the traditional method's shortcomings of a large footprint, low wastewater treatment efficiency, and magnetic seed waste. As shown in Figure 1 below.

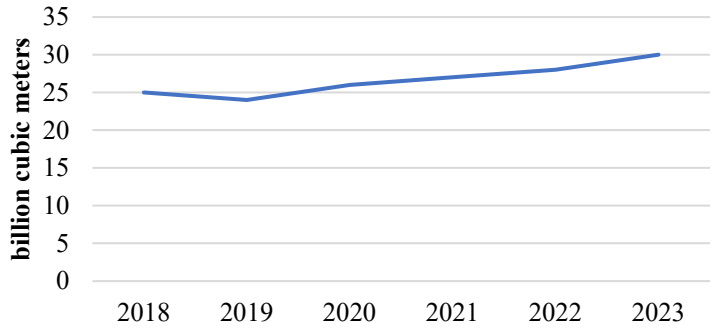

Figure 1. Tobacco wastewater discharge

1.2. Significance of Works Research

With the development of tobacco processing technology, the papermaking method for tobacco flake production has become the mainstream technology in tobacco processing due to its high material utilization rate, low tar content, and superior physicochemical properties. However, the papermaking-based tobacco flake production process generates a significant amount of wastewater. Through corresponding calculations, the average wastewater volume produced per 1 ton of tobacco flakes ranges from 50 to 70 cubic meters. This wastewater contains a diverse array of pollutants, including tobacco components, cellulose, nicotine, ester compounds, and other substances. Simultaneously, such wastewaters typically exhibit high concentrations of suspended solids (SS) and obvious eutrophication characteristics, manifested as extremely high chemical oxygen demand (COD) and biological oxygen demand (BOD). Additionally, the high toxicity of microbial components in this wastewater poses potential threats to both the ecological environment and human health, necessitating the use of combined treatment processes to degrade different pollutants. Nevertheless, existing tobacco wastewater treatment processes suffer from issues such as complex workflows, high chemical dosage, large land occupation, and treatment devices often have problems like high energy consumption, easy clogging, and frequent maintenance requirements. Therefore, there is an urgent need for a new type of tobacco wastewater treatment device to optimize the treatment process.[2]

2. Research Content

2.1. Design scheme

The project incorporates a magnetic seed delivery pump, a micro-flocculation chamber, a super-magnetic separation device, a special media drum, a micro-jetting device, a flocculation machine, and a magnetic suction conveyor belt recovery device, as shown in Figure 2 below. The micro-flocculation chamber utilizes a ramped baffle structure, while the drum features embedded cylindrical permanent magnets in its middle and lower sections. Inside the drum, a substrate composed of fine stainless steel is arranged to form a high-gradient magnetic field.

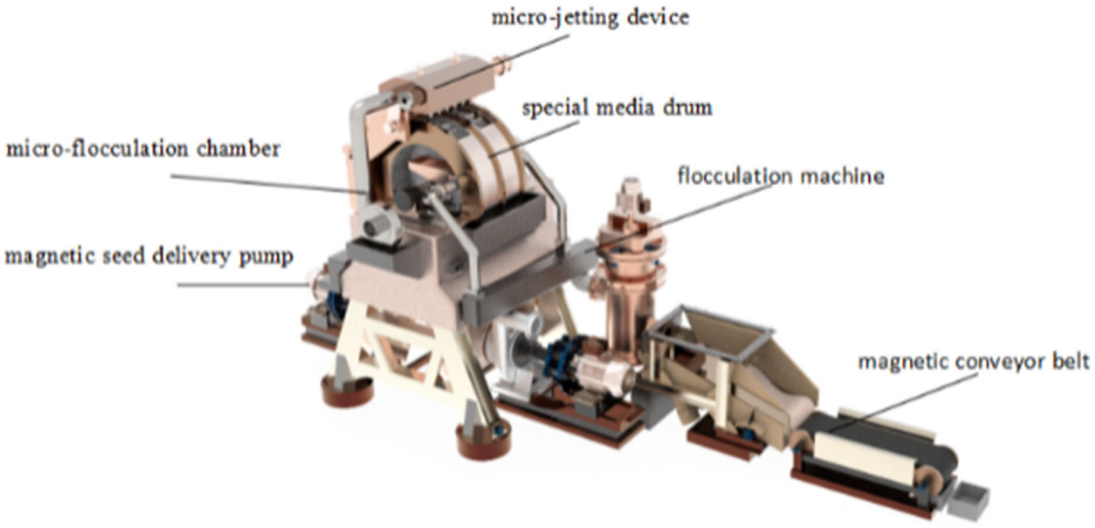

Figure 2. Overall design of the device

Tobacco wastewater produced by papermaking method is passed through the upper water inlet, and the magnetic seed dropping pumps on both sides pass Fe3O4 magnetic seeds and flocculant PAC into the micro-flocculation device through centrifugal principle, and the magnetic seeds are exchanged with wastewater in two-phase flushing at the slanting baffle plate to realize the hedge flocculation of suspended materials and organic wastes. Adding flocculant and magnetic seeds in the flocculating water area, on the one hand, magnetic substances can play the role of flocculation, insoluble organic matter, ammonia and nitrogen-containing substances to accelerate the aggregation together, and at the same time, flocculant can make the substances have micro-magnetism, which is convenient for the subsequent super-magnetic separation device to separate the flocculated material.

In the middle and lower part of the drum is provided with embedded permanent magnet, and the inner part of the drum is provided with substrate made of delicate stainless steel, under the action of huge magnetic field force generated by the permanent magnetic material, it makes the flocculent attached to the substrate, and rotates to the upper part under the rotation of the drum, and at this time, the micro-jet device sprays out the water, and the flocculent is detached from the substrate and enters into the magnetic seed recycling part under the action of the impact force and the gravity, and so on.

The deflocculator first breaks up the flocculent and the magnet into a free state, further realizes the separation of sludge and magnetic powder through the transverse vibration device, and finally adsorbs and recovers through the magnetic suction conveyor belt so that the waste and the magnetic powder enter into the recycling box respectively, realizing the reuse.

1) Magnetic Seed Dispenser

Magnetic seed injection pump sprayed by the magnetic seed is the use of plasma surface organic polymerization technology in the Fe3O4 magnetic particles deposited on the surface of acrylic acid (AA) film made of Fe3O4 magnetic seed, acrylic acid with carboxyl functional group, the preparation of the magnetic seed of the pollutants in the sewage adsorption has a very good effect, especially in the sewage, lignin, cellulose, polyacrylic acid, organic pollutants, such as CODCr, and sodium sulfate, sodium carbonate and inorganic pollutants such as sodium silicate. Sodium sulfate, sodium carbonate, sodium silicate, and other inorganic pollutants. A research group used self-developed plasma surface organic polymerization of AA's Fe3O4 magnetic seed material, superconducting magnetic separation in sewage treatment experimental research. Experimental results show that the sewage containing the above pollutants, after superconducting magnetic separation treatment, has a removal rate of pollutants as high as 85% or more, CODCr removal rate is 91%. As shown in Figure 3 below.

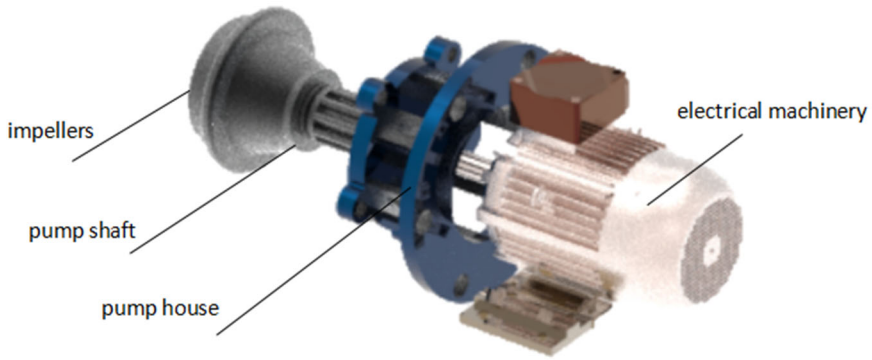

Figure 3. Magnetic Seed Discharge Pumps

This magnetic seed drop pump is based on the design of a liquid centrifugal pump, which utilizes the centrifugal force generated by the high-speed rotating impeller to feed the liquid into the pressurized water line. There are the impeller, retaining ring, pump shaft, motor, pump casing, and other structures in the device. The working process of this drop pump is a process of energy transfer and conversion. Before the pump is started, the pump casing is filled with the mixed liquid of magnetic seed and flocculant PAC, after which the motor is started, the pump shaft drives the impeller to rotate, and the mixed liquid rotates together with the impeller under the drive of the vane, which in turn generates centrifugal force, resulting in the liquid being thrown along the vane pipeline towards the outlet of the impeller and obtaining energy, and then the liquid enters into the worm casing at a high speed, and in the In the snail shell, the liquid decelerates due to the expansion of the flow channel and converts part of the kinetic energy into hydrostatic energy, and finally flows out of the pipeline at a higher flow rate into the flocculation work area, and there is a flow monitoring system on the centrifugal pump, which allows the flow rate to be adjusted to realize the cyclic circulation of the ejected magnetic seeds.

2) Microflocculation chamber

Wastewater enters into the flocculation chamber from above, and the magnet is put into the flocculation chamber through the drop pump to obtain the driving force, and under the design of the slope baffle, the magnetic seeds and flocculants are impacted by the drop pump and hit the slope baffle to realize the upward movement, and the downward movement of the wastewater to form a counterpoise. In this process, the organic pollutants and small particles in the wastewater coalesce under the action of magnets and flocculants, adsorbed around the magnets, and then aggregated into clusters under the action of coagulants, realizing the purpose of purifying wastewater. Finally, the wastewater is removed from below, and the flocs are absorbed by the super-magnetic separation matrix above, as shown in Figure 4 below.

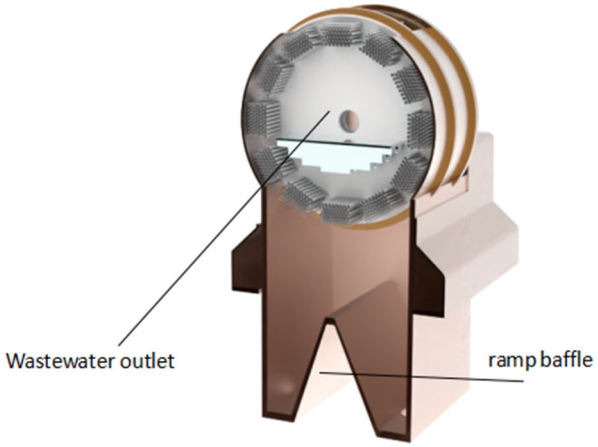

Figure 4. Microflocculation chamber

3) Super Magnetic Separator

Currently, the most widely used permanent magnet is NdFeB, which is divided into two types: sintered NdFeB and bonded NdFeB. Since bonded NdFeB is magnetic in all directions and corrosion-resistant, according to the alkaline conditions of the waste liquid and the requirements to be met by adsorption, this device adopts the bonded permanent magnet material that does not require plating, is corrosion-resistant, and can form the magnetic field of the desired arrangement. The super magnetic separation device includes a rotatable drum, a cylindrical substrate disposed on the drum, and a permanent magnet material embedded in the middle and lower portions of the drum, the cylindrical substrate disposed on the drum being thick on the inside and thin on the outside, and a plurality of cylindrical substrates being arranged in a staggered manner. The permanent magnet material is neodymium iron boron, which is characterized by a strong magnetic force and permanence. Placed in the magnetic field generated by the permanent magnet, the substrate due to the different size and shape of different parts of the substrate, resulting in the sparsity of magnetic lines on the substrate, which in turn generates a higher magnetic field gradient, in

the high gradient magnetic field, flocculent is more likely to be adsorbed. As shown in Figure 5 below.

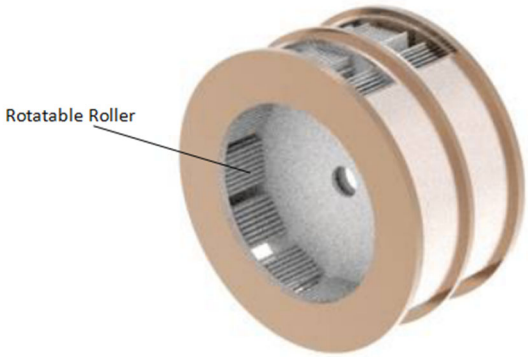

Figure 5. Rotating disk

4) Micro-jetting Device

The micro-jet device is placed on top of the rotating super-magnetic separation through the support structure, using an array of jet nozzles, when the rotating disk adsorbed with flocculent leaves the magnetic field area formed by the permanent magnetic material, and reaches the top, the high-speed jet of small water streams is utilized to provide the impact force, and the magnetic seed and the impurities it carries are washed away together with the magnetic seed and fall into the collection slanting tank under the effect of gravity and impact, and the follow-up is carried out afterwards. Afterwards, as shown in Figure 6 below, the magnetic seeds are recycled, and the residues are utilized.[3]

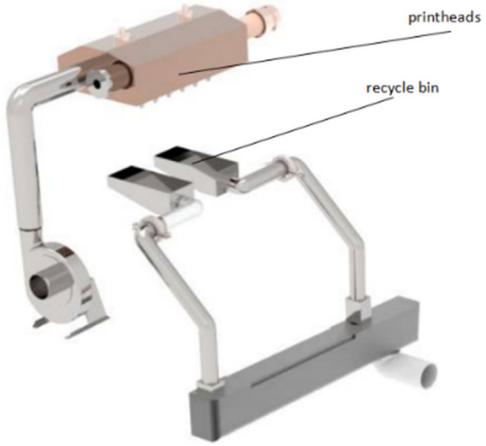

Figure 6. Micro-jetting Device

5) Magnetic Seed Recovery Unit

Flocculent into the deflocculator through the magnetic field generated above, making the magnet to produce demagnetization, stirring the flocculent broken, and then through the deflocculator's special flow channel design and high-speed rotating machinery to produce a strong shear force, so that the flocculent in the magnetic species to become a free state, to facilitate the subsequent recovery of the magnets. To solve the flocculent adhering to the magnet, there is a lateral vibration device is designed for the magnet in the deflocculator. After the action of the lateral vibration, the magnet and sludge adhere, reducing the final magnet recovery rate.

Break due to excessive squeezing.

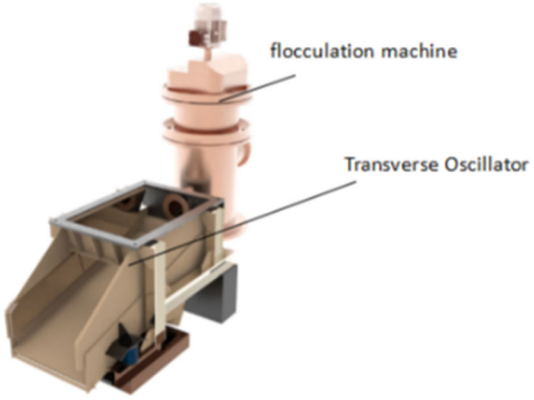

Figure 7. Magnetic Seed Recovery Unit

2.2. Feasibility analysis

1) Feasibility analysis of hedonic flocculation

If the initial velocity of the magnetic seed into the flocculation chamber is 16.5 m/s, then the magnetic seed will move forward and be resisted by the wastewater. The baffle plate is inclined to the horizontal direction at a certain angle, similar to the structure of the retaining wall, which can reduce the backwinding and make the fluid move upward more, compared with the baffle plate without inclination can be better with the wastewater to form convection, the angle of the inclination angle can be changed, so that the magnetic seed put flow rate changes to adapt to different flow rates of wastewater, to achieve a better coagulation, and this part of the experiments need to be verified to adapt to the actual production needs. At the same time, the magnetic seed is affected by the fluid, after collision with the baffle, the speed decreases, and after collision of the magnetic seed speed is too small will lead to the flocculation process can not be effective, when the baffle tilt angle of 45 °, n = 0.75, the calculation of the v1 = 10.44, so after the baffle of the change of direction of the role of the magnetic seed can be smooth upward movement, and can be and the wastewater flocculation of convection.

2) Feasibility analysis of magnetic species adsorption

According to the market research as well as experimental measurements and calculations, it is known that the magnetization strength of the Fe3O4 magnetic species used in this device is 66092A/m, and the radius of the magnetic species is 20 μm, and the simulation of the permanent magnets, as shown in Fig. 7 is just a third of the three gradient plates, and the magnetic field at the tip are up to 12,000A/m2, so it can be obtained that the gradient of the magnetic field in the space in the cylindrical drum where the permanent magnets are distributed The average value is about 12000 A/m2. It is also obtained that the fluid flow rate in the device is about 0.8 m/s, the hydrodynamic viscosity of the entrained magnetic seeds is about 1.1×10-3 Pa-s, the magnetic seed flow rate after collision with the baffle plate is about 10.44 m/s, and the water flow rate after collision of the two water streams is about 0.2 m/s. The Fm is about 1.2-10-11N, the Fd is about 5.2- 10- 12N, the magnetic field force on the magnetic seed is greater than the drag force of the fluid on the magnetic seed, so the magnetic seed can be smoothly adsorbed to the substrate.

3) Feasibility analysis of micro-injection device treatment

At present, the magnetic recovery system of the super-magnetic separation system consists of two parts: the integral magnetic drum turntable and the recycling tank, and there is a rotating brush between the magnetic drum turntable and the recycling tank, which will bring out the magnetic sludge flocs during the rotation of the magnetic drum, and the magnetic sludge flocs will be brought out, and the magnetic sludge flocs will enter into the magnetic seed recycling equipment to realize the separation of the magnetic seed from the sludge with vigorous stirring, and the recycling of the magnetic powder will be realized in the magnetic flocculating and recycling of magnetic seeds in the two times of the magnetic flocculating and recycling process. Utilization. However, due to the strong magnetic force of the magnetic drum turntable in the two processes, the rotating brush often cannot completely strip the magnetic seeds from the magnetic drum, resulting in the waste of magnetic seeds, the magnetic loss of the magnetic drum, and the high energy consumption of the equipment, thus affecting the efficiency of the next cycle.

To solve these problems, a micro-jet processor is added to this device to separate the flocculent from the substrate. Now choose the nozzle, its aperture is 1.4mm, the flow rate is 3L/s, g takes 9.8m/s2, ρ=103kg/m3, h=0.2m, substitute the data can be obtained P=0.49Mpa. Water pressure is required to be able to wash down the magnetic species and impurities; at this time, the water pressure should be in the range of 0.1~1MPa. At the same time, taking into account that it can not destroy the high-gradient magnetic medium, the high-gradient magnetic medium can withstand the maximum The maximum pressure that the high gradient magnetic medium can withstand is 1MPa, and the pressure of this device is within the flushing pressure range, which is feasible.[4]

3. Domestic and Foreign Research Status and Development Trends

At home and abroad, there are many treatment methods for tobacco wastewater, such as biochemical process, strong oxidation process, biochemical-strong oxidation process, and pure physical process, etc. The following are the current treatment methods:

1) Chen Yuancai uses UASB and UBF high concentration of granular sludge sludge bed, and by the filler and its attached biofilm, composed of a filter media layer coupled with two SBR aerobic processes running in series, the effluent CODCr removal rate can reach more than 90%.

2) Li Youming coagulation - anaerobic - aerobic - depth treatment of wastewater, anaerobic UASB, effluent COD, BOD5, SS, and chroma of the water indicators are better than the tobacco flake factory's currently available treatment system.

3) Wang Min in Jiangxi, a cigarette factory renovation project using “hydrolysis acidification + contact oxidation + coagulation and precipitation” on the sewage treatment, the effluent quality of water to meet the urban wastewater recycling landscape environmental water quality (GB/T18921-2002) of the water landscape class standards.

4) Li Yeting used the “hydrolysis acidification - two-stage BAF - ozone - activated carbon filtration” process, so that the sewage can be reused. In summary, the current research on the tobacco wastewater treatment process has a lot of research hotspots that are mainly concentrated in the multi-stage combined treatment process and the AOPs method. To a multi-stage combined treatment process as the main, with the AOPs treatment process as a supplement.

Tobacco wastewater treatment mainly refers to the paper industry wastewater treatment process, but taking into account the many types of organic matter in tobacco wastewater, composition fluctuations, in the treatment process should be combined with the composition of the specific tobacco wastewater treatment process planning, the treatment process to try to reduce the pollution of the environment, but with the increase in the sewage discharge standards, the above methods are lacking in the perfection of the place, so the need for depth treatment of some of the Pollutants, taking into account the economy, so that the development of enterprises and environmentally friendly coordination and coexistence.[5]

4. Innovation

1) Structural innovation

Instead of the traditional static flocculation, an inclined baffle structure is designed, where the baffle is inclined at a certain angle to the direction of magnetic seed placement, which shortens the flocculation time and improves the flocculation efficiency.

2) Application innovation

The use of micro water spray device instead of a disk blade reduces the damage to the inner wall of the device and prolongs the service life.

The application of super-magnetic separation technology to treat tobacco wastewater reduces the floor space, improves the treatment efficiency, and reduces the emission of organic matter in tobacco wastewater.

3) Combined innovation

Combining hedge flocculation and magnetic seed separation, while improving the treatment effect, it also realizes the recovery of magnetic seeds.

4) Method innovation

Improvement of the current wastewater treatment methods, the use of multi-stage treatment methods, and the use of new flocculation and deflocculation devices for its treatment can guarantee the treatment efficiency while improving the recycling rate.

Acknowledgements

2024 National innovation and entrepreneurship training program for college students (Project Number: S202410497083).

References

[1] Li Pengfei. Overview of the research progress of the tobacco wastewater treatment process[J]. Science and Informatization, 2020(11):1.

[2] Li Hanbo. Quick troubleshooting and assembly techniques of HTB-ZK10.0/35 acid-resistant ceramic pump[J]. Hunan Nonferrous Metals, 2009, 25(5):4. DOI:10.3969/j.issn.1003-5540.2009.05.015.

[3] Chen Zhidong, ZHOU Fayou, XIE Wei. Detection method of negative pressure pump control signal: 201010571196 [P][2025-04-18].DOI: CN102032166 B.

[4] Cao Pan. Research progress of wastewater treatment process in the tobacco industry[J]. Resource Conservation and Environmental Protection, 2015(12):1. DOI:CNKI:SUN: ZYJH.0.2015-12-072.

[5] Hua Tao, ZHOU Qixing, JIA Hongyu. Key design and ecological issues of artificial wetland wastewater treatment process[J]. Journal of Applied Ecology, 2004, 15(7):1289-1293.