

National technical university of Ukraine
"Igor Sikorsky Kyiv polytechnic institute"
Educational and scientific institute of energy saving and energy management
Department of automation of electrical and mechatronic complexes

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for a master's degree
according to the educational and professional program "Engineering of intelligent electrical
and mechatronic complexes"
specialty 141 "Electric power engineering, electrical Engineering and electromechanics"
on the topic: " Electromechanical equipment automated plastic waste sorting system and
technology for their disposal "

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I certify that in this master's thesis there are no
borrowings from the works of other authors
without appropriate references.

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Kyiv – 2024

**National technical university of Ukraine
"Igor Sikorsky Kyiv polytechnic institute"
Institute of energy saving and energy management**

Department of automation of electrical and mechatronic complexes

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TASK

for a master's thesis for a student

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1. Dissertation topic "Topic", supervisor of the dissertation First name, Last name, scientific degree, academic title, approved by the order of the university from "___" _____ 2024
No _____
2. Deadline for submission of the student's dissertation December 9, 2024
3. Object of study
4. Imprint
5. List of tasks that need to be developed
6. Approximate list of illustrative material
7. Indicative list of publications

8. Master thesis chapter consultants

Section	Surname, initials and position of the consultant	Signature, date	
		Task accepting status	Task execution status
Chapter 1. (status quo)	Doctor of Sciences (Technical), Professor Boichenko Sergii		
Chapter 2. (analytical)	Doctor of Sciences (Technical), Professor Boichenko Sergii		
Chapter 3. (Challenges and measures)	Doctor of Sciences (Technical), Professor Boichenko Sergii		
Chapter 4. (Elaboration of Startup Project)	Candidate of Economic Sciences, Associate Professor Shevchuk Nataliya		

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Schedule

No.	Name of the stages of the master's thesis	Deadline for the stages of the master's thesis	Note
1	Processing special literature On technologies for sorting plastic waste	01.06-21.10.2024 p.	
2	processing special literature on technologies for pyrolysis disposal of plastic waste	01.06-21.10.2024.	
3	Formulation of the goal, object, subject and tasks of dissertation. Construction of a general methodological scheme (algorithm block diagram) for the performance of qualification work	01.06-21.10.2024.	
4	Electromechanical equipment and an automated system for sorting plastic waste	Up to 28.10.2024.	
5	Electromechanical equipment and an automated system for pyrolysis disposal of plastic waste	Up to 04.11.2024.	
6	Preparation and submission of the article in a scientific journal	Up to 04.11.2024.	
7	Characteristics of system for sorting plastic waste and pyrolysis disposal (dimensions, technological parameters, automation level)	Up to 04.11.2024.	
8	Developing a startup project of system	Up to 11.11.2024.	

	for sorting plastic waste and pyrolysis disposal		
9	Drafting of notes, presentations, reviews	18.11.2024 p.	
10	Participation in the conference	27.11.2024	
11	Preparation for the previous one protection Representation work at the department	04.12.2024 p.	
12	Accounting comments, recommendations and defense preparation	Up to 13.12.2024 p.	

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If consultants are identified. The supervisor of the master's thesis could not be appointed as a consultant.

Abstract

Master's thesis

“Electromechanical equipment automated plastic waste sorting system and technology for their disposal”

The thesis consists of 161 pages, 15 tables, 43 figure and 75 references (on 170 pages).

The recycling of plastics plays a pivotal role in fostering a circular economy. For mechanical recycling to be effective, it is essential to initially categorize plastic waste based on type, color, and dimensions to retrieve high-quality plastics for further processing. In the realm of chemical recycling, certain plastics need to be precluded as they can impair the recycling process. The sorting of plastic materials at Materials Recovery Facilities is increasingly dependent on advanced automated technologies. Accurate identification of plastic types is essential for effective sorting, which is typically achieved through spectroscopic analysis, enhanced by machine learning and artificial intelligence. This paper outlines recent advancements in the integration of machine learning/artificial intelligence within plastic recycling processes, showcasing the current technologies for identifying and sorting plastics. A review of publicly available data has allowed us to identify commercial sorting equipment and assess its sensors, efficiency in sorting various plastic types, main applications, capacity, and precision. While significant progress has been made in plastic sorting, challenges remain in the separation of plastic films, dark plastics, and multi-polymer materials. The field is

continuously evolving, with ongoing developments and novel approaches expected to further enhance the automation of plastic sorting.

Keywords: Polymers, classification; Processing, mechanical and electrical equipment

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Introduction

The imperative for effective plastic waste management is underscored by the escalating global consumption and disposal of plastics, which pose significant environmental challenges. Effective recycling is crucial for transitioning towards a circular economy, where waste is minimized, and resources are conserved. The recycling process, particularly mechanical recycling, hinges on the initial categorization of plastic waste by type, color, and dimensions to ensure the retrieval of high-quality plastics for subsequent processing. This initial sorting phase is vital as it directly influences the efficiency and efficacy of subsequent recycling stages.

In today's era, plastic waste has become one of the most serious environmental challenges facing the world. As plastic production continues to surge, its accumulation in the environment continues to accelerate. According to statistics, only about 9% of the world's plastic waste is recycled, 12% is incinerated, and a large number of plastics are not properly disposed of, which leads to plastic waste everywhere in the natural environment, causing serious damage to the ecosystem in many ways.

In the Marine environment, plastic waste poses a direct threat to Marine life. Every year, many Marine organisms such as whales and seals are injured or even killed by plastic entanglement. Large plastic garbage will not only entangle Marine organisms, but also block their digestive tract, affect feeding, and lead to insufficient energy intake and death. Plastic decomposition in the ocean formed

by microplastics is difficult to detect and great harm, its particle size is less than 5mm, can enter the food chain, through biological enrichment, so that pollutants accumulate in the body of organisms, and then affect the physiological function of organisms, the balance of Marine ecosystems have a profound impact. In addition, the study found that microplastics have entered every corner of human life, such as in tap water, salt, beer are found, and even in human feces are also detected microplastic particles, which indicates that human health is also a potential threat.

In this context, the effective treatment of plastic waste is of vital importance for achieving sustainable development. As a key way to solve the problem of plastic pollution, plastic recycling helps to reduce resource waste, promote the development of circular economy, reduce the dependence on original resources, reduce environmental pressure, and protect the ecological environment and human health. Therefore, in-depth research on plastic waste treatment technology and management strategy has urgent practical needs, to provide scientific basis and practical guidance for the realization of resource recycling and environmental protection.

Goal. Improvement of the system of electromechanical equipment and automation for sorting and pyrolytic recycling of plastic waste.

The object of the study is the accumulation, collection, sorting and processing of plastic waste, simulation modeling of the system of automation of sorting and pyrolytic recycling of plastic waste.

The subject of the study is the technological scheme of sorting, the

technological scheme of the pyrolysis plant, the mnemonic scheme of the electromechanical equipment of the plastic waste disposal complex (sorting and processing (pyrolysis)).

The scientific novelty consists in the application of an integrated approach and the construction of the mnemonic diagram of the electromechanical equipment of the complex for the recycling of plastic waste (sorting and processing (pyrolysis)).

Practical results. Tire recycling is a critical problem due to the large accumulation of plastic waste around the world (about billions), which creates environmental problems. Automated systems are designed to optimize this process by sorting, shredding and processing tires with minimal manual intervention, thus increasing productivity and reducing labor costs. (According to the latest report of the QYResearch research team "Global tire recycling market Report 2023-2029", it is expected that the global tire recycling market will reach 5.22 billion US dollars in 2029, and the compound annual growth rate of 1.9% in the next few years. (Source: Tire Recycling Market Report: Compound annual Growth rate of 1.9% CAGR in the next few years - Eastern Wealth Network Stock Market)

Research background and significance

With the increasing global consumption of plastics and the resulting large amounts of plastic waste, improper disposal of plastic waste has led to serious environmental pollution and resource waste. Traditional manual sorting of plastic waste is inefficient, labor-intensive, and inaccurate. Moreover, as the volume and

complexity of plastic waste continue to grow, there is an urgent need for more advanced and automated sorting solutions. The development of electromechanical equipment and related technologies provides an opportunity to improve the efficiency and accuracy of plastic waste sorting.

This thesis attempts to address two key issues.

1. How to make garbage classification more accurate?
2. How to avoid secondary pollution when disposing plastic waste.

Chapter 1 STATUS OF ELECTRICAL AND MECHANICAL EQUIPMENT AND PLASTIC WASTE

1.1 Current status of plastic waste

The main components of plastics are polyethylene, polypropylene, polyvinyl chloride, polystyrene, etc. These components are thermoplastic resins with stable chemical properties, corrosion resistance, good heat resistance and water resistance [36]. Plastics are widely used in industry, life, agriculture, automotive plastic parts greatly reduce the quality of the car itself, thereby reducing vehicle emissions, improve combustion efficiency; The use of plastic bags, plastic bottles, plastic straws, etc., has brought great convenience to human life; The use of agricultural mulching film is conducive to soil heat preservation and humidification and the absorption of soil nutrients. Therefore, plastic has been used in all walks of life, plastic to provide convenience to human beings at the same time, plastic is not easy to degrade, not easy to be consumed by nature, plastic waste can be seen everywhere in public places, affecting the beauty of the environment, and the ingredients contain potential harm, with rivers and human dumping garbage into the sea, plastic waste will enter the sea on a large scale. Plastic waste has a small volume, diameter of less than 5mm plastic particles, called microplastics, microplastics in the Marine environment is difficult to capture, and great harm, through the food chain and food plastic packaging is easy to enter the human body, its small size, large specific surface area, strong ability

to absorb pollutants, There are A large number of persistent organic pollutants such as polychlorinated biphenyls and bisphenol A in the Marine and water environment. These pollutants will be adsorbed on plastic particles and enter the stomach of organisms, causing heart disease and reproductive diseases, and causing serious harm to organisms [37].

Plastics can be divided into thermoplastics and thermosetting plastics, thermoplastics have the characteristics of softening by heating and hardening by cooling, plastic bags, plastic bottles, straws, cling film, etc. are all thermoplastics, which are elastic and pressure-resistant. Thermosetting plastics are not soluble or fusible after curing, and their hard shape is not easy to change [38].

Litter pollutes the human environment, especially the marine environment. Currently, there are about 7 billion tonnes of plastic waste on the planet, which is growing at a high rate, and only 9% of the huge amount of plastic waste is recycled, 12% is incinerated, and the rest is not effectively managed and discarded in the environment. Eurostat announced a total global plastic production of 335 million tonnes in 2016, and increasing by 4% every year, East Asia, Europe, North rubbish pollutes the human environment, especially the marine environment. Currently, there are about 7 billion tonnes of plastic waste on the earth, and the trend is growing rapidly, and only 9% of the huge amount of plastic waste is recycled, 12% is incinerated, and the rest is not effectively managed and discarded in the environment. Eurostat announced that in 2016, 335 million tonnes of plastics were produced globally, and this is increasing by 4% per year, with the largest amount

of plastics being produced in East Asia, Europe, North America, and South America.

Litter entering the oceans is bound to cause serious harm to marine life, marine ecosystems and human health. Plastic waste takes decades to decompose in the oceans, and large volumes of plastic can entangle marine organisms, causing them to drown, respire, die, or be eaten by other organisms. According to statistics, 130,000 whales become entangled in plastic in the ocean each year, and 40,000 seals in the Bering Sea are killed by plastic entanglement each year¹²]. Larger plastics not only entangle organisms and kill them, but also clog up their digestive tracts and cause a feeling of fullness, resulting in inefficient feeding and low energy intake, leading to death. A type of plastic that has a greater impact on organisms is called ‘microplastics’, which is made up of large-volume plastics that have gradually weathered into particularly small particles, with a particle size of less than 5mm, which is difficult to see with the naked eye. This new type of pollutant has attracted a great deal of attention from human beings in recent years, and has also been referred to as the ‘oceanic PM₂₂₂₂. PM₂₅’, microplastics and traditional plastics, compared to the migration of transformation ability, easy to enrich toxic substances, and chemical properties of stability, once it will be accidentally eaten by animals, the degradation of plastics in living organisms will be released in the process of bisphenol A, a substance that can lead to heart disease and reproductive disorders, styrene plastics in the process of degradation of styrene monomer, which is a recognised carcinogen [this is a carcinogenic

substance], and the degradation process of styrene plastics, the release of styrene monomer. This is a recognised carcinogen [1]. Microplastics have a large specific surface area and are particularly hydrophobic, so they are prone to adsorb pollutants in the environment. When these pollutant-enriched plastics are accidentally ingested by marine organisms, persistent pollutants, such as organochlorine pesticides, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs), will produce toxic effects in organisms, and then be passed on through the food chain, endangering ecosystems and ultimately endangering the health of human beings [3]. A report published by the European Society of Gastroenterology confirmed for the first time that microplastics have been found in the human body, and found that 20 plastic particles per 10g of human faeces could be detected, with as many as 9 types of plastic particles. These plastic particles are ingested by the test subjects through the consumption of plastic-packaged food and drinks, as well as fish. These microplastics can enter the bloodstream, lymphatic system and even the liver, not only physically damaging the organs, but also destroying the immune system by filtering out toxic chemicals, and microplastics are not degradable, so the effects will last for the next generation. Microplastics have been found in every corner of human life, in tap water, in salt, in beer, and their global pollution has become a major problem.

The distribution of plastics in the global ocean is mainly concentrated in the North Pacific Ocean, North Atlantic Ocean, South Pacific Ocean, South Atlantic Ocean, and Indian Ocean, mainly due to the wide area of these seas and the

formation of ocean currents in the circulation loop, which makes the plastics float and concentrate with the ocean currents [20]. Cozar et al. [21] analysed that the content of plastics in the inner part of the circulation vortex is greater than that of the outer part, and the content of plastics in the outer part of the vortex is less than 50 g/km², whereas in the centre of the vortex the content of plastics reaches 1500 g/km²~2500 g/km². The plastic content in the centre of the vortex reaches 1500 g/km²~2500 g/km². Obbard et al. [22] found that there are plastics such as polystyrene, acrylic acid and man-made fibres in sea ice collected from different seas in the Arctic Ocean region, and that sea ice freezes a large number of microplastics, which is not easy for degradates to be transported to the North and South Poles, and this seriously affects the global water environment. However, nowadays, with global warming and melting of sea ice, the plastic debris in the sea ice is released and spreads in the global ocean. Marcus et al [23] estimated that there are more than 5 trillion plastic fragments floating in the world's oceans according to the oceanographic model, with a weight of more than 25×10⁴t. Ivar et al [24] studied the pollution of microplastics in the ocean and the current status and future impacts of microplastics. Ivar et al. [24] studied the current status and future impacts of microplastic pollution in the oceans. Microplastics are mainly found in plankton, vertebrates, sandy and muddy sediments. Microplastics are not easily degraded, with 88 per cent of plastic debris between 22°N and 38°N being less than 10 mm.

In The New Plastics Economy - Rethinking the Future of Plastics at the

2016 World Economic Forum, the Ellen MacArthur Foundation of the United Kingdom noted that plastic use has increased 20-fold in the last 50 years and is expected to double again in the next 20 years. Currently, plastic waste weighs 1:5 the weight of fish, and if left unchecked, plastic waste will weigh more than fish in 50 years.

With the acceleration of urbanization, the problem of plastic waste generated by cities has become increasingly prominent, and has become one of the environmental challenges that need to be solved globally. In China, the problem is equally serious, with many negative impacts on the ecological environment, urban management and residents' lives.

Plastics have been widely used in modern urban life due to their characteristics of lightness, durability and low cost. From daily shopping plastic bags, food packaging, to all kinds of plastic products in industrial production, its figure is everywhere. However, it is this widespread use that has led to a sharp rise in the amount of plastic waste in cities. As one of the countries with the largest population and rapid economic development in the world, China's urban scale continues to expand, the consumer market is increasingly prosperous, and the production of plastic waste has also shown a continuous growth trend.

In every corner of the city, plastic waste can be found everywhere. On the streets, plastic bags that are discarded at will fly in the wind, which not only affects the beauty of the city, but also may block sewers and cause problems such as urban waterlogging. In parks and scenic spots, garbage such as plastic bottles and food

bags are scattered in the grass and corners, destroying the natural landscape and causing direct damage to the ecological environment. What's more, some plastic waste enters rivers, lakes and other water bodies, and eventually flows into the ocean, posing a huge threat to Marine ecosystems. According to statistics, China's coastal cities discharge an alarming amount of plastic waste into the ocean every year, which floats and decomposes in the ocean to form microplastics, which are mistakenly eaten by Marine organisms and passed through the food chain, which may eventually affect human health.

The difficulty of urban plastic waste disposal can not be underestimated. Due to the chemical stability of plastics, the natural degradation process is extremely slow, usually taking hundreds or even thousands of years. Traditional landfill treatment occupies a lot of land resources, and plastic waste in the landfill process may leak harmful substances, pollute the soil and groundwater. Although incineration can reduce the volume of garbage, it will produce toxic gases such as dioxins and cause secondary pollution to the atmospheric environment. Recycling, as a relatively environmentally friendly treatment method, faces many challenges in China. On the one hand, the recycling system is imperfect and the recycling channels are scattered, resulting in a large amount of plastic waste not being effectively recycled. On the other hand, the cost of recycling is high, and the market price of recycled plastics is relatively low, making the enthusiasm of recycling enterprises is not high.

China's Guangdong Province, a province on the southern coast of China, is

one of China's most populous and largest provinces in terms of economic aggregate, and is known for its strong economic strength, open foreign trade and vibrant private economy. Guangdong Province borders Fujian to the east, Jiangxi and Hunan to the north, Guangxi to the west, and the South China Sea to the south. The Pearl River Delta region is the most economically developed region in Guangdong Province. It is one of the most populous provinces, with a huge labor resource and consumer market. Guangdong Province has long ranked first among all provinces in China in terms of economic aggregate, and has a strong manufacturing base, especially in electronic information, home appliances, textiles and clothing, food and beverage industries with obvious advantages. At the same time, Guangdong Province is an important financial, trade and logistics center in China.

According to the 2023 government Work report, with economic, technological and social progress, Online consumption has brought more and more plastic waste to the rapid development of express delivery and take-out industries. When analyzing the composition of domestic waste in Guangdong Province, it was found that rubber and plastic waste (plastic, rubber, leather) in Guangdong Province accounted for 21.34% of the total domestic waste [92]. From 2009 to 2019, the proportion of plastic waste in domestic waste increased rapidly in a year, reaching 397.39%.

From the issuance of an upgraded version of the "plastic limit order" in 2020, most traditional enterprises in Guangdong Province, such as supermarkets,

pharmacies and restaurants, no longer provide consumers with disposable plastic products, but provide corresponding environmental alternatives. For example, supermarkets and pharmacies advocate the public to use environmentally friendly shopping bags when shopping, and replace all plastic shopping bags with degradable environmentally friendly plastic bags. The price of this plastic bag is relatively high, which effectively inhibits the public's purchase of plastic shopping bags to a certain extent, and the public's habit of bringing their own shopping bags and recycling shopping bags is gradually developing. From the perspective of catering companies, large catering companies are more inclined to use degradable plastic products in the choice of packaging boxes and bags. From the perspective of KFC and other fast food chains, paper packaging is used for the packaging of goods, and all straws are replaced with paper straws, and the spoon is wooden. As a "large consumer" of plastic packaging in the beverage industry, most beverage stores have replaced the material of straws with paper, plastic containers with paper containers, and even plastic containers are degradable plastic materials. However, in the farmers' market and all kinds of stores, because the value of the goods they sell is not high, durable, cheap and convenient plastic bags have become the first choice for merchants and consumers, compared with the higher price and non-durable degradable plastic bags.

1.2 Definition and application status of electromechanical equipment

Electromechanical equipment is a comprehensive concept that organically integrates multidisciplinary knowledge and technologies such as mechanical engineering, electrical engineering, electronic technology, automatic control technology, and information technology. The mechanical part provides the physical structure and motion basis of the equipment, such as mechanical transmission devices and working mechanisms, realizing the transmission of force and the conversion of motion forms. The electrical system provides the power source for the equipment, including motors, power supplies, etc., and is also responsible for power distribution and management. Electronic technology endows the equipment with intelligent functions. For example, sensors are used to collect various physical quantity information, and the controller makes decisions and controls according to the preset program and sensor feedback. Automatic control technology enables the equipment to operate automatically in accordance with predetermined rules and requirements, realizing precise position control, speed control, temperature control, etc. The integration of information technology enables data communication, remote monitoring and management between equipment, improving the overall synergy and intelligence level of the equipment. Through the close combination of these disciplinary technologies, electromechanical equipment has acquired remarkable characteristics such as automation, intelligence, high precision, and high efficiency, and is capable of accomplishing a wide variety of complex tasks, ranging from simple material

handling to high-precision machining and manufacturing, and from the automated control of industrial production processes to the operation and management of intelligent systems.

Electromechanical equipment has a wide range of applications in garbage classification, as detailed below:

1. Intelligent Garbage Classification Equipment

- For example, some devices can recognize various types of garbage through dialect conversations and accurately open the corresponding trash bins according to needs. Such as the AI intelligent garbage classification equipment in Xinle Village, Suxi Town. Villagers can say the name of the garbage, and the equipment can quickly respond. It also has a real-time weighing function, records the weight of the garbage and gives points, which can be exchanged for daily necessities. This equipment can also record non-standard disposal behaviors around the clock in real-time, automatically detect, warn, and push the record situation, realizing an "online + offline" supervision closed loop. In addition, there are similar devices that can automatically collect recyclables at the door, such as the garbage sorting and recycling machine "Niu Ren", which can move, has a load capacity of 100 kilograms, and can automatically open and close the elevator and call residents after installing the corresponding module in the elevator.

2. Garbage Sorting Machine

- It can automatically sort mixed garbage and separate plastics, paper, organic matter, batteries, packaging materials, etc., for subsequent recycling,

simplifying the traditional garbage sorting process, reducing manual intervention and costs. There are various models and are widely used in garbage cleaning stations, transfer stations, treatment plants, composting yards, and incineration plants.

3. Mechanical Equipment for Sorting Recyclable Garbage

- It includes screening equipment, sorting equipment, etc. The screening equipment can remove large debris and separate garbage of different sizes; the sorting equipment uses sensor and robotic arm technologies to separate recyclables such as metals and plastics for reuse. Its technological process includes design, manufacturing, use, and maintenance, and each link is important.

4. Garbage Classification and Recycling Equipment with Multiple Functions

- For example, an electromechanical device for garbage classification and recycling has a drying chamber, an incineration chamber, and a pulverization chamber at the top, which can store and process different types of garbage simultaneously. The heat in the incineration chamber can be transferred to the water tank to heat water and generate steam for heating and drying the garbage in the drying chamber, and the pulverization mechanism in the pulverization chamber can cut and pulverize the garbage.

5. Electromechanical Integrated Garbage Classification and Treatment Device

- By setting a stirring shaft and magnet blocks in the treatment box, it can

adsorb iron filings and impurities on the surface of metal garbage, and the scraper scrapes them off and flows into the compression box for compression; the roller in the feeding box can squeeze the garbage, and the pulverization roller pulverizes the squeezed garbage for better subsequent treatment.

6. Intelligent Recycling Equipment Entering the Community

- For example, the intelligent garbage classification and recycling equipment in Wukang Street is connected to the backstage digital control center through the Internet and is equipped with automatic sensors, weighing devices, and other devices. After swiping the card or face recognition, the cabinet door automatically opens, and after the garbage is thrown into the corresponding box, the cabinet door automatically closes. When the storage volume of the trash bin reaches a certain proportion, the platform will send an early warning text message to the management personnel. Residents can obtain points by correctly delivering perishable garbage to exchange for garbage bags or participate in recyclables to obtain points and get free garbage bags.

7. Automatic Garbage Collection System

- It uses a vacuum pipeline to collect and transport garbage. Residents put the garbage into the drop-off port, and the garbage will be pumped to the central garbage collection station in a completely sealed state through negative pressure technology, separated, compressed, and pushed into a sealed garbage container, and then transported to the disposal site by a garbage truck. The whole process is fully enclosed, eliminating secondary pollution, reducing the number of garbage

transports, improving the efficiency of sanitation work, reducing traffic pressure, noise, and carbon emission pollution, realizing fully automated operation and avoiding human contact with garbage. For example, the relevant system of Zhuhai Lianyi Electromechanical also includes its designed automatic kitchen waste collection system, which has a fully sealed design, no odor, no sewage leakage, avoids mosquito problems, requires no manual treatment, and improves the efficiency of garbage collection and ensures the cleanliness of the kitchen.

8. Garbage Classification and Treatment Device

- For example, an electromechanical integrated garbage classification and treatment device includes a feeding port, a feeding box, a rotating motor, a driving motor, etc. After the garbage is poured into the feeding box, the rotating motor drives the roller to squeeze it, and the pulverization roller pulverizes it; the magnet blocks on the stirring shaft in the treatment box adsorb the iron filings and impurities on the surface of the metal garbage, and the scraper scrapes the iron filings and impurities into the first compression box, and the hydraulic cylinder, push rod, and push block compress it; the support plate, movable plate, and other structures at the bottom of the stirring shaft can push other garbage into the second compression box for compression.

9. Intelligent Garbage Classification Equipment Entering the Campus

- For example, the intelligent garbage classification equipment 启用 in Huji Town Primary School Qiaodang Campus. Teachers and students can use this equipment for garbage classification and disposal and obtain points. The school

also conducts relevant knowledge into the classroom activities to cultivate students' environmental awareness and plans to encourage parents to participate through the form of "holding small hands with big hands".

Chapter 2 WASTE TREATMENT SYSTEM BASED ON GUANGDONG YUEKONG ELECTRIC CO.

Guangdong Yuekong Electric Co., Ltd represents a significant player in environmental protection technology, specifically focusing on plastic waste management through advanced mechatronic solutions [44]. Established as a pioneering entity in sustainable waste management, the company has developed comprehensive expertise in plastic waste classification and pyrolysis treatment systems, integrating cutting-edge automation technologies with mechanical engineering principles. The company's core business areas encompass three primary domains: automated waste classification systems utilizing machine learning algorithms and computer vision technology, achieving sorting accuracies of up to 95.8%; pyrolysis treatment facilities operating at temperatures of 450-500°C with precise control systems maintaining $\pm 0.3^{\circ}\text{C}$ accuracy; and integrated control systems incorporating modern industrial automation protocols [45]. The training objectives aligned with both academic requirements and industrial applications, focusing on developing practical expertise in mechanical systems operation, automation control implementation, and system integration methodologies. The program aimed to bridge theoretical knowledge with industrial applications, targeting specific competencies including PLC programming, process control optimization, and mechanical system maintenance, while maintaining alignment with Industry 4.0 principles [46]. The company's commitment to environmental sustainability is evidenced by its research and

development initiatives, maintaining an annual investment of 15% of revenue in technological advancement and process optimization, particularly in areas of artificial intelligence application and energy efficiency improvement in waste treatment processes.

The company will design the sorting system and pyrolysis system of the company according to the design concept in Figure 2.1

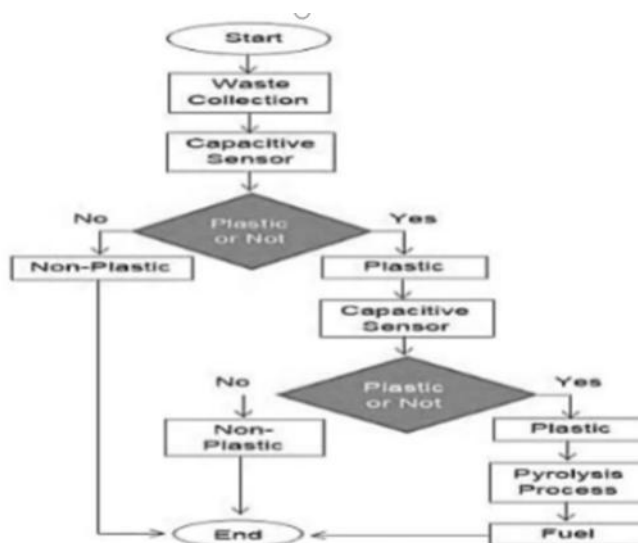


Fig. 2.1 Shows the Conceptual Design of the Project

2.1 Electromechanical equipment automated plastic waste sorting syste

Plastic materials are typically lightweight and capable of holding a vast array of consumable and household liquids, which renders them one of the most prevalently used materials for domestic packaging. Plastic packaging can be fabricated from diverse resin varieties, with PET, HDPE, LDPE, PVC, PP, and PS being among the most commonly employed ones. These plastic materials boast numerous recycling applications. When it comes to sorting recyclables, two

methods are available: manual sorting and automated systems. In the case of plastic materials, improper sorting that mixes different resin types, like PVC and PET, may trigger the release of hydrochloric gases [66].

Manual sorting depends on the plant staff who visually recognize and pick out plastic bottles as they move along the conveyor belt [67]. Subsequently, these bottles are sorted into the corresponding containers. However, manual sorting might not be an ideal choice for recycling facilities with high processing volumes. It has also been observed that the frequent turnover of workers on the sorting line has led to challenges in maintaining consistency throughout the plastic separation process [68].

Automated sorting systems adopt a detection system or a mixture of several detection systems to tell apart various types of plastic recyclables. These detection mechanisms make use of advanced technologies to sort plastics automatically, with the sorting criteria being resin type, shape, color, or a blend of these aspects. When it comes to plastic materials, automated sorting falls into two main categories: whole bottle sorting, also known as macro-sorting, and flake sorting, or micro-sorting. Flake sorting systems are engineered to sort plastics in granular form and have the ability to handle vast amounts of the material [66].

State - of - the - art technologies in automated sorting:

While flake-sorting systems, or micro-sorting, are gradually being embraced in the recycling industry, whole bottle sorting, namely macro-sorting, remains the dominant form of automated sorting. During macro-sorting, a

detection system identifies plastic recyclables according to their resin type, color, or even physical traits. After analysis, these plastic bottles are ejected from the conveyor belt into their corresponding storage bins with devices like high-pressure air jets [69]. Optical Sorting systems, Near Infrared Systems, and X-Ray technologies are some commonly used technologies in automated sorting setups.

Optical Sorting Systems leverage visible light to segregate HDPE plastic bottles by color. For single-color separation, optical systems employ black and white cameras. For instance, they can detect colored bottles among a stream of non-pigmented, natural HDPE bottles. Optical sorting systems capable of multiple color separations utilize a color camera. Nowadays, commercially available systems can sort a diverse range of colors, even very faintly translucent colored bottles.

Near Infrared (NIR) Systems operate within a part of the light spectrum invisible to the human eye. When plastic bottles are exposed to NIR signals, each plastic resin absorbs specific wavelengths and transmits others, generating unique characteristic responses that sensors can detect. NIR can be configured to distinguish among numerous plastic resin types. The benefit of using NIR is that surface contaminants like labels don't impede the sorting process's efficiency. Nevertheless, it's crucial to note that NIR detection systems can't detect bottles blocked by other packaging. Thus, it's essential to present bottles to the detector one by one to optimize accuracy and, consequently, quality.

The development of automated systems for sorting post-consumer plastic

dates back to 1989. Two years later, in 1991, the first commercial system that could separate PVC from PET by using X-Ray technology was introduced [70]. Since then, research and development activities in this field have been surging rapidly, especially with the growing awareness of engineering life cycle aspects like design for recycling, reuse, and remanufacturing.

Currently, automated systems are quite efficient in sorting plastic materials. However, they demand a hefty investment in specific technologies and machinery. These technologies are not suitable for low to medium recycling volumes, as seen in countries like Malaysia. In light of this situation, a study was carried out to explore the feasibility of imaging technology for automated sorting. For this preliminary study, plastic recyclables of PET/PETE, HDPE, and PVC resin types were chosen and categorized into two main groups of plastic recyclables: PET and non-PET, with HDPE and PVC falling into the non-PET category. PET bottles are typically designed for edible liquids such as mineral water and fruit juices, while non-PET bottles are often used for chemical-based liquids like household detergents and pesticides.

System Description: The intelligent sorting system consists of the material handling system and the detection system.

The material handling system is made up of the hopper and the conveyor system. Each component of the system has gone through the design methodology process, which involves identifying design requirements, generating design concepts, and evaluating these concepts to select the final design concept.

Development of the System Structure for the Machine Vision Module: At the outset, the feasibility of employing machine vision to detect plastic materials and sort plastics was explored. Initially, the sorting approach was centered around the materials of plastic bottles. By narrowing down the plastic types to be sorted to just PET/PETE and non-PET materials, the study's emphasis was placed solely on a binary pattern recognition task. The findings of this research can be incorporated as an embedded framework for the development of an automated system leveraging machine vision.

As depicted in Figure 2, the overall system design structure comprises three principal components: pre-processing, feature extraction, and classification. For the creation of the automated sorting system, image-processing techniques were utilized. This entailed the use of feature extraction and image recognition modules, meaning that the sorting of plastic bottles or packages was image-based. The images were preprocessed first, and multiple features like the histogram, area, perimeter, centroid, and hue were extracted in advance.

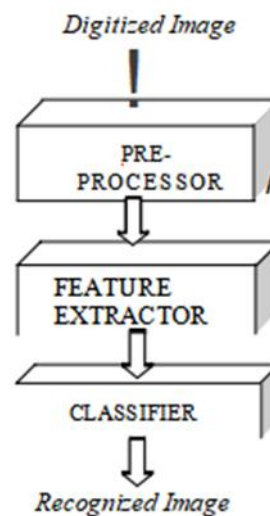


Fig. 2.1 The overall system structure

Design and development work

Design of the Hopper: The primary challenge in designing the hopper is to manage recyclables with diverse shapes and sizes while guaranteeing a single-file, or singulated, flow onto the conveyor belt. To meet this demand, multiple design concepts were conceived and appraised in light of the design requirements.

The hopper was engineered with two plates affixed to its wall. These plates were positioned at varying heights and on opposite sides of the wall. Their main role is to decelerate the flow rate of the recyclables passing through. At the base of the hopper, there's a rotating blade that rotates slowly, also aiming to regulate the flow.

From this initial concept, several alternative design proposals emerged. One such option involved using two rotating blades – one installed in the upper section of the hopper and the other in the lower part. The upper rotating blade spins at a slower pace than its lower counterpart to precisely control the recyclables' flow rate.

Eventually, the final design concept incorporates a specialized tray. This tray, which functions as a flow control mechanism, features apertures of different sizes corresponding to the size categories of the recyclables. Placed at a downward slope at the hopper's exit, it ensures a more controlled and efficient discharge of the recyclables.

The main requirement for the machine vision system is the capability to identify plastic bottles arriving at random times in random positions and

orientations on a moving conveyor belt. Moreover, the speed in the image acquisition and treatment as well as in pattern recognition plays a fundamental role for industrial applications in view of the amount of waste to be processed.

Garbage sorting technology is a very important research topic in the field of environmental protection. With the rapid growth of China's GDP, waste production is also increasing. The survey shows the output of domestic waste in large and medium-sized cities in China in the past ten years, as shown in Figure 2.2. In 2022, the domestic waste produced by large and medium cities in China will reach 244.759 million tons, and increase at an annual rate of 5%. However, most waste disposal methods, such as incineration and landfilling, cause great pollution to the environment [2]. How to deal with this garbage has become an urgent problem

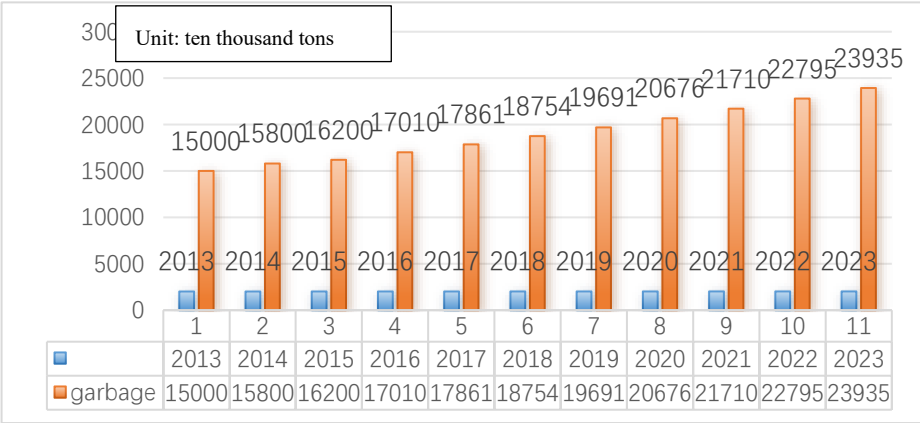


Fig2.2 China's large and medium urban solid waste production

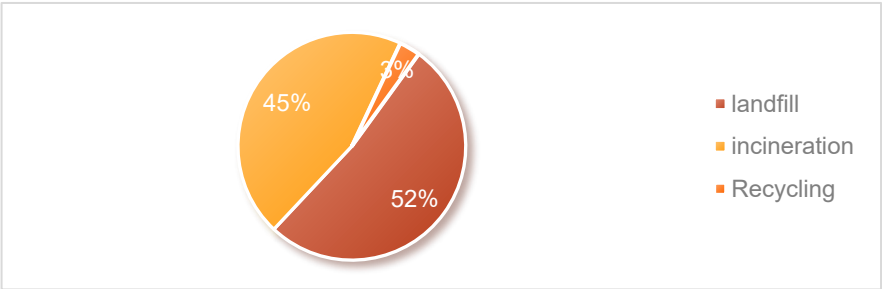


Fig 2.3 Domestic Waste Disposal Methods

Waste plastic waste has a special position in municipal waste, which belongs to the category of high value-added waste. In the current situation, its proportion in municipal waste has reached more than 16%, which is a reliable source of data [3] as a basis.

However, in China, the current situation of waste plastic waste disposal is not optimistic. This is mainly due to the backwardness of the sorting technology, which directly leads to the plastic waste sorting utilisation rate is far lower than the level of developed countries. Figure 2.4 clearly shows how traditional waste plastic waste is treated.

Among them, manual sorting is one of the more traditional treatment methods. However, this method has an obvious disadvantage, which is low efficiency. In the process of manual sorting, the staff need to spend a lot of time and energy to distinguish between different types of plastic waste, and is affected by human factors, the accuracy and speed of sorting are difficult to guarantee.

In addition, plastics incineration and plastics pyrolysis technologies were also commonly used treatment means in the past. However, these two technologies have brought about serious environmental problems. In the process of plastics incineration, a large amount of exhaust gas will be produced, which contains a variety of harmful substances, such as sulphur dioxide, nitrogen oxides, dioxins and so on. These harmful substances will spread with the air and pollute the surrounding atmosphere, endangering human health and affecting the survival of animals and plants. At the same time, the plastic pyrolysis technology is not

perfect. During the pyrolysis process, not only will waste gas be generated, but also waste water. This wastewater often contains high concentrations of organic substances and heavy metals. If it is discharged directly without proper treatment, it will cause serious pollution to soil and water resources, destroying the ecological balance and bringing great harm to the environment as a whole. Such harm can be long-term and irreversible, with far-reaching effects on the local ecosystem and the quality of life of the inhabitants.



Fig 2.4 Waste Plastics Disposal Methods

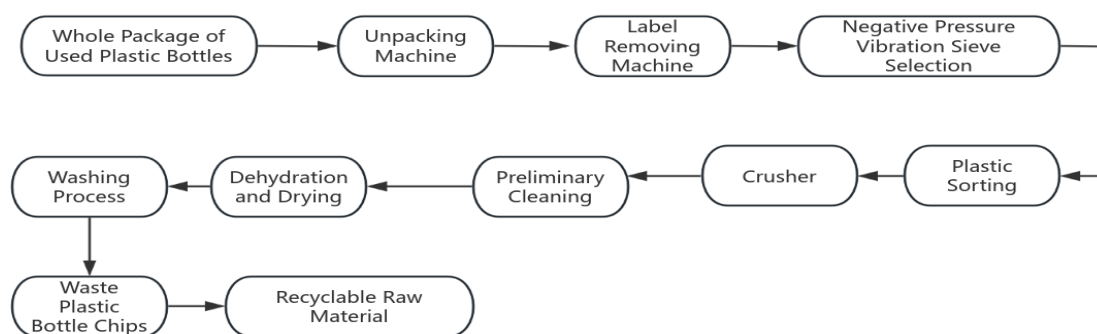


Fig 2.4 Flow chart of plastic waste disposal

Table 2.1

Advantages and Disadvantages of Various Sorting Methods for Plastic Waste

Sorting Methods	Advantages	Disadvantages
Manual sorting	Low cost and easy to operate	Low efficiency, high labour intensity, hazardous to health

Mechanical sorting	Fast, efficient and accurate	High cost, not fully mechanised
X-ray sorting technology	Can quickly distinguish the composition of different materials	Expensive equipment, big safety hazard
Wind Sorting	Simple equipment, high efficiency	High operating environment requirements, easy to clog
Flotation and Sinking	Easy to operate, low cost,	Serious secondary pollution
Near infrared spectroscopy	Able to accurately and quickly identify the composition of materials	High equipment requirements, expensive

The company has designed a waste sorting system to improve the precise separation of waste plastic waste. The main objectives of the design of the equipment are; Firstly, the domestic waste is selected by wind or other sorting methods, and the waste plastic waste is coarse sorted out to obtain the mixed plastic waste material; Secondly, the category information and location information of materials are collected through the camera room. Finally, the mechanical equipment grabs the material moving on the conveyor belt.

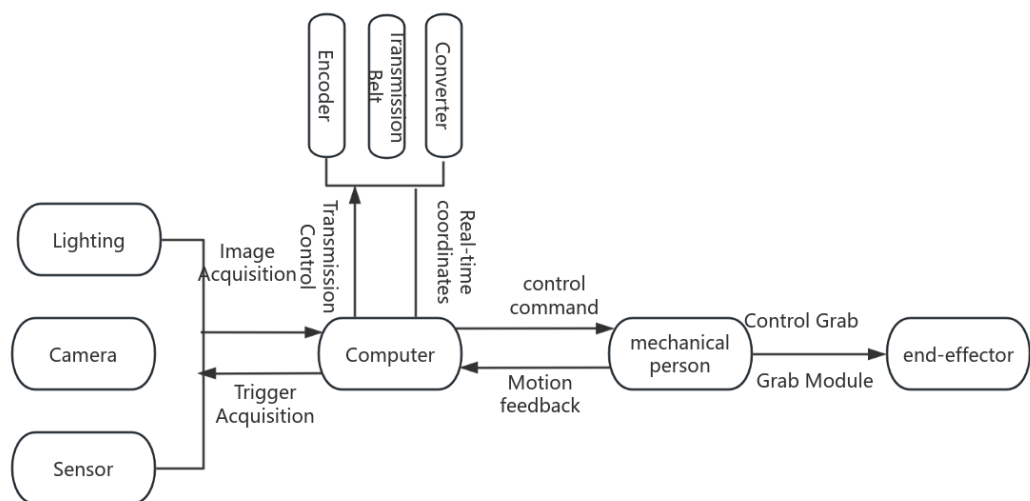


Figure 2.5 Schematic diagram of the overall design of the refuse sorting system

The system model diagram as shown in Figure 2.6 is established through the garbage sorting diagram. The system is mainly composed of vision module, transmission module and grasping module. The vision module is mainly composed of cameras, lenses and light sources. It is mainly responsible for collecting pictures of materials to make data sets, and collecting real-time information of materials in the process of garbage sorting. The transmission module is mainly composed of conveyor belt, encoder and frequency converter, which is mainly used for the control of conveyor belt speed, position recording and material transportation in the system. The grasping module is composed of robot, vacuum generator, solenoid valve and end actuator, etc., which is mainly used to perform the action of grasping materials, and spray the materials from the conveyor belt to the specified material sorting basket. The three modules are controlled by the computer and work together to realize the intelligent grasping of the robot. The design of this system can realize the efficient sorting and recycling of garbage, reduce the labor cost, and improve the efficiency and accuracy of garbage sorting.

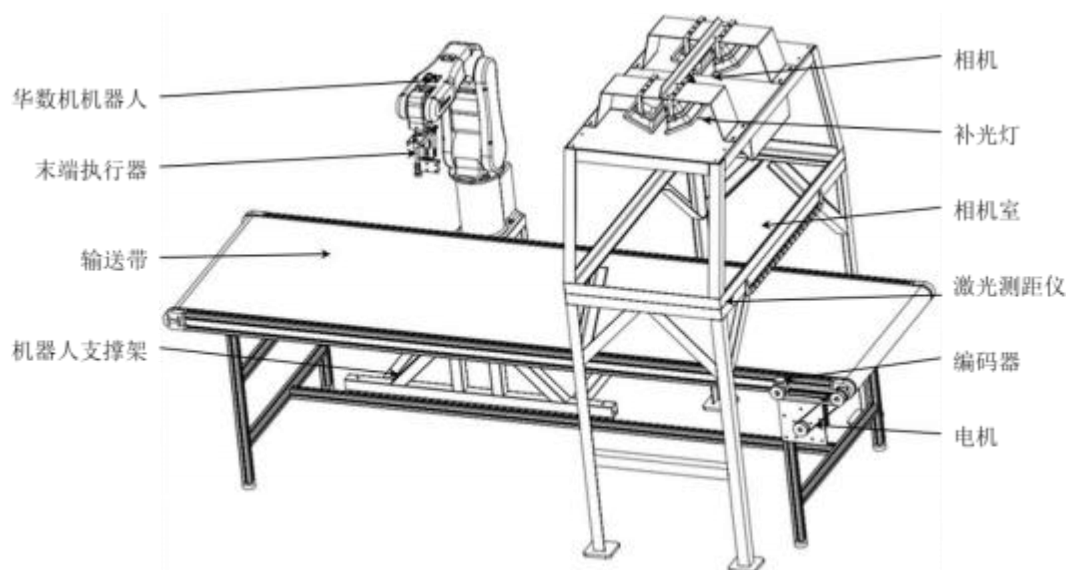


Fig 2.6 Modelling of the waste sorting system

Through the cooperative work of the above three main systems, namely vision module, transmission module and grasping module, the whole GPA garbage sorting system can complete the intelligent grasping work of garbage on the conveyor belt. The main working principle of the system is: first, the plastic waste is evenly distributed on the conveyor belt, and the material is transported to the camera room through the conveyor belt. Secondly, the computer-controlled camera collects the pictures of the material, obtains the category information and position information of the material through the target detection algorithm, and obtains the attitude information of the material through the attitude detection. Finally, the obtained information is transmitted to the robot through the computer, and the robot is controlled to grasp the material, and the material is sprayed into the specified material sorting basket through the high-pressure air jet end actuator, and the material sorting work is completed.

In the whole garbage sorting system, vision module, transmission module and grasping module are the core parts of the system hardware. The selection and design of these three hardware modules will affect the effect of the entire garbage sorting system. Therefore, in order to build a complete garbage sorting system, After determining the main workflow of the garbage sorting system, it is necessary to select and design the three modules of the system, and rationally select the hardware suitable for the system according to the design of the overall overall scheme. The following describes the core hardware parameters of the system.

□ □ vision module hardware selection

a) Camera selection

In the garbage sorting system, the camera is responsible for image acquisition, and its acquisition quality directly affects the accuracy of recognition. Compared with ordinary cameras, industrial cameras are easy to install, strong structural strength, long continuous working time, high frame rate, short shutter time, and strong data transmission ability. Industrial cameras mainly include two types: CCD camera and CMOS camera. CCD camera is a semiconductor device that converts light into electric charge, which can convert optical signals into electrical signals, and store and transmit them inside the chip. CMOS cameras achieve image acquisition by converting the charge of each pixel into a voltage and output a digital signal through an amplifier circuit.

In the process of garbage sorting, the camera collects objects moving on the conveyor belt. When the objects move, the exposure time becomes longer, resulting in the relative motion imaging of the objects on the Sensor, resulting in the phenomenon of dragging. As a result, cameras need to have shorter exposure times and faster frame rates.

After comprehensive consideration, the company finally selected the MV-CA050-20UC camera of Hikvision Company as the camera of this system. The appearance of the camera is shown in Figure 2.7. The detailed parameters are shown in Table 2.2. The camera has the characteristics of high resolution and low cost, which meets the requirements of the system for cameras.



Fig 2.7 MV-CA050-20UC Imager Physical Drawing

Table 2.2

MV-CA050-20UC Imager Detailed Parameters

Performance	Parameter	Performance	Parameter
Sensor Type	CMOS, global shutter	Signal-to-noise ratio	39.5dB
Sensor Model	OnSemi PYTHON5000	Exposure Time	59 us ~ 10 sec
Image Size	4.8umx4.8um	Black & White, Colour	Colour
Target Size	1"	Data Interface	USB3.0, USB2.0 compatible
Resolution	2592×2048	Typical Power Consumption	3.5 w@5 VDC (USB powered)
Maximum Frame Rate	71.8 fps@2592×2048	Quality	Approx. 56g
Gain	0 dB~15 dB	Power supply	12 VDC, USB powered

b) Lens selection

Industrial lenses use arrays of optical lenses to project objects onto sensors. Moreover, industrial lenses have high resolution and ultra-low distortion design technology, and distortion technology can reduce reflection loss and glare, improve contrast and color reduction, and thus improve image clarity [39]. High resolution and low distortion are realized through the design of multiple lenses. In the imaging principle of the camera, the focal length f of the lens, the width size w of the camera sensor component, the photo width W and the distance D of the object from the camera plane constitute the basic parameters. The focal length of

the camera can be calculated by the formula (2.1). The camera imaging schematic shown in Figure 2.4 shows the relationship between the above parameters.

$$f = w \frac{D}{W} \quad (2.1)$$

According to the overall design of the system scheme, the distance between the conveyor belt plane and the camera is $D=1.1$ meters, and the width is 1 meter, that is, $W=1$ meter. The target size of the MV-CA050-20UC camera selected in this paper is $12.8\text{mm} \times 9.6\text{mm}$, and the focal length of the lens is 14.08mm by replacing it with the formula (2.1). Taking into account the selection of camera models and focal length size specifications, the final choice of Hikon MVL-KF1228M-12MPE 12 million fixed focus 12mm lens



Fig 2.8 MVL-KF1228M-12MPE Lens Physical Drawing

c) Light source selection

In the vision module, selecting the right light source can improve the camera image quality and recognition success rate. According to the different luminous materials, light sources can usually be divided into halogen lamps, LED light sources, etc. [40]. Among them, LED lamps have the advantages of high efficiency and energy saving, long life, high color reproduction and low heat output. In addition, LED lights also have a small volume and weight, easy to control and

adjust, can meet the needs of different scenes, so it is widely used in camera scenes [41]. This system selects the LED light of the model of Minhongshi MHS-B15, which is often used for road security system monitoring lighting, with 360° rotating bracket, can adjust the light Angle according to actual needs. Figure 2.9 shows a physical image of the LED light.



Fig 2.9 Physical drawing of light source

After completing the light source selection in the camera room, it is also necessary to determine the irradiation mode of the light source. As shown in Figure 2.10 (a), with direct lighting, no matter how to adjust the aperture and exposure of the camera, it is difficult for the material to form a relatively uniform light on the conveyor belt. Therefore, in this paper, the light is illuminated to both sides of the phase machine room in the way of light deflection, and the diffuse reflection of light is used to evenly spread the light on the surface of the conveyor belt, thus forming a relatively uniform lighting condition, as shown in Figure 2.10 (b)



Fig 2.10 (a) Direct light

(b) Scattered light

□ Transmission module hardware selection

a) Conveyor belt design

The transmission module is mainly composed of conveyor belt, motor, encoder and frequency converter, which is mainly used for speed control of conveyor belt in the system, position recording and material transportation work. The conveyor belt is used as the background plate for camera identification, and has special requirements for the reflectivity of the belt surface. It is required that the light shining on the conveyor belt is diffuse reflection, and the illumination on the belt side of the conveyor belt is uniform [42]. Therefore, this paper chooses the black matte conveyor belt, the specific size is 3000cm long, 1000cm wide, 75cm high, and the motor model is 6GU-10K, as shown in FIG. 2.12. Because the system has strict requirements on the speed of the conveyor belt, the motor is controlled by the frequency converter. Select EM100 inverter produced by Shenzhen Sine Company as shown in Figure 2.11.



Fig. 2.11 Physical diagram of frequency converter

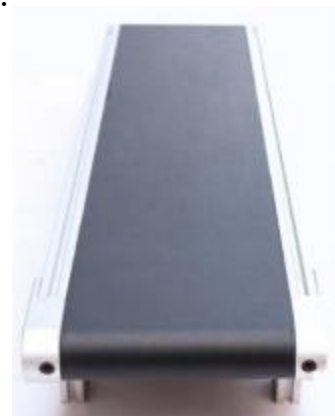


Fig 2.12 Conveyor Belt Physical Drawing

b) Encoder selection

Encoder is a sensor that converts motion or position into digital signals, which is mainly used to measure the speed and Angle position of the motor or the motor drive shaft, and convert the mechanical motion into an electrical signal. Its function is to monitor the motion state of the motor or drive shaft in real time, convert the rotation Angle into digital or analog signals and output them to the controller, so as to achieve accurate position control and speed control [43]. According to their working principle, encoders can be divided into two categories: absolute encoders and incremental encoders [44]. The absolute encoder is slightly more expensive than the incremental encoder, but it has high precision, strong anti-interference ability, reliable data, and power off memory. In this system, the BRT12 absolute encoder produced by Shenzhen BRit Technology is shown in Figure 2.13, and the detailed parameters of the encoder are listed in Table 2.4.



Fig 2.13 Encoder Physical Drawing

The encoder is an important part of the digital collection module in the waste sorting system of mechanical and electrical equipment. The encoder is an important part of the digital collection module in the robot waste sorting system, and is installed on the synchronous wheel next to the motor. It records the rotation data of the motor in detail through its own resolution, and calculates the real-time

speed of the conveyor belt according to the diameter of the main moving roller.

Table 2.4 Detailed encoder parameters

Performance	Parameter	Performance	Parameter
Resolution	9600	Analogue code values	ASCII
Communication Protocol	ModBus-RS484	Operating Temperature	-40 ~ +80°C
Operating Current	50-100MA	Maximum starting torque	0.006NM
Linearity	0.10%	Weight	200G
Kernel Refresh Cycle	50US	Electrical life	>100000H
Maximum mechanical speed	1000 RPM	Maximum shaft load	Axial 20N, Radial 80N

□ Hardware selection and design of grasping module

a) Robot selection

As the main body of the garbage sorting system, industrial robots need to receive signals from other modules to complete the grasping action. HSR-JR605 of Wasu robot was selected in this paper, as shown in Figure 2.13. The robot is a common six-degree of freedom series robot, with six joint axes, each joint axis has a rotation Angle, high flexibility, relatively low price, strong stability, cost-effective, is a high-quality choice for garbage sorting robots. Table 2.5 lists the detailed parameters of the robot.



Fig. 2.13 Appearance of HUAC Robot

Table 2.5 Detailed robot parameters

Performance	parametric		PERFORMANCE	Parameters
Control Axis	6		I/O Parameters	32 Input, 31 Output
Rated load	5kg		Rated Power	1.2kW
Maximum movement radius	746mm		Rated Voltage	Single-phase AC220V
Repeat positioning accuracy	$\pm 0.02\text{mm}$		Rated Current	6.5A
Mounting method	Floor mounted, upside down mounted, side mounted		Robot Weight	55KG
Range of motion	$\pm 200^\circ$	Rated speed	Body Weight	222 °/s , 3.87rad/s
	-180°/0		Body Weight	180 °/s , 3.14rad/s
	+80°/+240°		J3	225 °/s , 3.93rad/s
	$\pm 180^\circ$		J4	235 °/s , 4.10rad/s
	$\pm 115^\circ$		J5	222 °/s , 3.87rad/s
	$\pm 360^\circ$		J6	360 °/s , 6.28rad/s

The electronic control system is the core part of the robot, which is composed of HPC controller, servo motor driver, I/O module and teaching panel. Among them, the IPC controller, servo motor driver and I/O module are integrated into the electric control cabinet of the robot, as shown in Figure 2.14. Based on an industrial embedded computer platform, the IPC controller runs on a real-time Linux system and integrates efficient robot motion control algorithms. Servo

motor drivers are used to control servo motors for high precision position drive systems. The I/O module mainly provides the external interface for the practical application of the robot, with a total of 16 general input and output channels. In this system, it is mainly used to control the on-off of the solenoid valve to complete the grasping work of the robot.



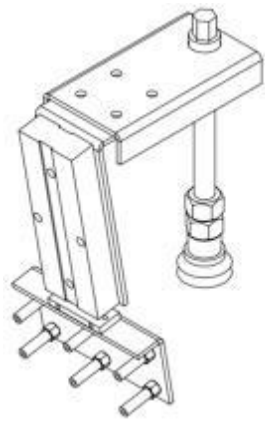
Fig 2.14 Physical drawing of ASUS robot electronic control cabinet

b) End-effector design

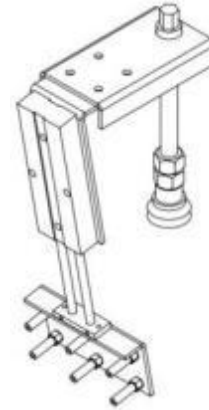
In order to complete the grasping task, end effectors such as vacuum cups and manipulator claws are usually installed on the end flanges of industrial robots. The sorting object of this paper is the common waste plastic waste in life, which is light in weight and relatively standardized in shape. The traditional end actuator is inefficient and expensive. Aiming at this condition, a high-pressure air jet end actuator mechanism is designed, as shown in Figure 2.15(a). The whole mechanism consists of a vacuum generator, a solenoid valve, a high-pressure nozzle, a support for hardware, a biaxial telescopic cylinder, a suction nozzle, etc.

When grasping materials, the vacuum generator is controlled to open, the material is adsorbed on the suction mouth, the robot is lifted to the specified

position, the sixth axis rotates to the appropriate Angle, and the two-axis cylinder is extended to drive the nozzle to move to the lower Angle of the material, as shown in Figure 2.15 (b). Open the nozzle solenoid valve, close the suction solenoid valve, and spray the material into the specified material sorting basket. The cylinder is designed in a two-axis mode, which on the one hand increases the structural strength of the cylinder, and on the other hand limits the rotation of the cylinder guide rod and holds the suction nozzle assembly below.



a) Shortening of end-effector



(b) End-effector elongation

Fig 2.15 End-effector configuration

The common machine end grasping device is generally divided into claw grasping mechanism and air suction grasping mechanism. In contrast, the claw grasping mechanism has the disadvantages of complex structure, slow opening and closing, and high cost. For the common waste plastic waste treated in this paper, its weight is light and its surface is smooth, so the grasping device equipped with air suction is selected as the end effector. The pneumatic suction cup is shown in Figure 2.16

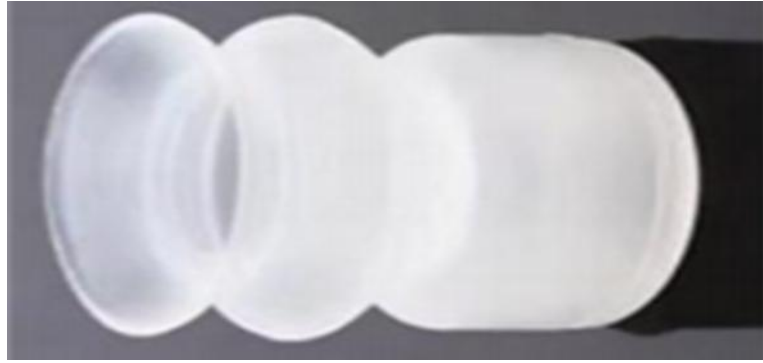


Figure 2.16 Vacuum suction cups

One of the most important standards of pneumatic suction cups is the diameter of the suction cups, and the diameter of the suction cups and the vacuum pressure jointly determine the maximum mass of the material that the suction cups can suck up [60]. The formula for calculating the diameter of the pneumatic suction cups is as follows:

$$D = \sqrt[2]{\frac{W*S}{\pi*P*n}} \quad (2.2)$$

Where D is the diameter of suction cups, W is the maximum adsorption mass (KG), S is the safety factor (horizontal adsorption $S \geq 4$, straight adsorption $S \geq 8$), N is the number of suction cups, and P is the vacuum pressure (-Kpa).

The above mainly introduces the overall scheme design of the waste plastic waste sorting system of the company's mechanical and electrical equipment, and draws the unit model diagram of the system. The main hardware in the vision module, transmission module and sorting module of the garbage sorting system is selected, including camera, conveyor belt and robot. At the same time, the design of end effector is discussed, and a design scheme of high pressure air injection end effector is proposed. The use of this end effector can increase the kinds of equipment sorting and improve the efficiency of material sorting.

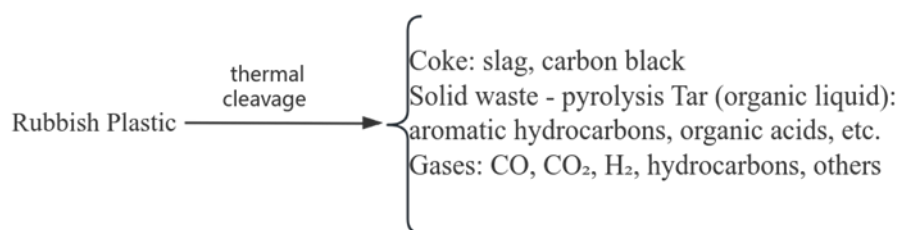
2.2 The company's plastic waste disposal technology

The company's plastic waste treatment technology is a major breakthrough in the field of environmental protection. Through advanced research and development, the company has designed an efficient system to meet the challenges posed by plastic waste. The technology combines mechanical sorting, chemical treatment and recycling processes to maximise the reuse of plastic materials. It not only reduces the amount of plastic that ends up in landfill, but also minimises the environmental impact by reducing emissions from the disposal process.

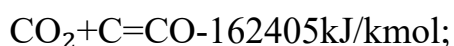
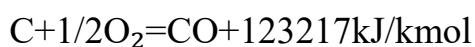
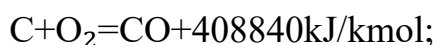
MSW is divided into several types. Tg was used to study their pyrolysis characteristics. Under different pyrolysis temperatures, the contents of HCl, NH₃, H₂S and their corresponding elements in coke were detected respectively after the raw material was converted to coke. The results showed that the precipitation rates of pollutants HCl, NH₃, and H₂S increased with increasing pyrolysis final temperature. During the pyrolysis process, the precipitation rate of HCl ranges from 60% to 92%, and reaches the maximum precipitation rate at 400°C, then the precipitation rate rises slowly, and then speeds up again at 600°C. The chlorine content in coke decreases with the increase of pyrolysis final temperature, and the chlorine content is 5%~15% at 800°C. The precipitation rate of NH₃ is 25%-62%, and the precipitation rate of NH₃ in different components of municipal live waste is different: In coke, the NH₃ of unsorted garbage reaches its maximum rate at 350°C, and the NH₃ of plastic, kitchen waste, and bamboo and wood garbage is the fastest in the 600°C~800°C range. The H₂S precipitation rate of urban plastic waste

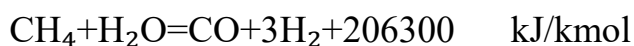
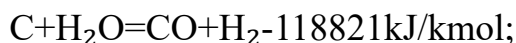
pyrolysis is 22%~53%, a large amount of H₂S is released from plastics at 200 °C ~500 °C, and H₂S is basically released at 600 °C, while H₂S from unsorted plastic waste is released at about 800 °C. The sulfur content in coke is the lowest 27%~40% at 700 °C and the highest at 600 °C.

The company uses pyrolysis technology to treat plastic waste, and the core principle of H₂S pyrolysis technology is the "pyrolysis" and "polymerization" pyrolysis process is expressed as follows:



The pyrolysis process of plastic waste is a series of continuous and complex chemical reactions, including the fracture between the bonds of large molecules and the polymerization and reforming of small molecules. In addition to processing a large amount of waste, the pyrolysis of plastic waste can also effectively recover heat energy, among which typical gas-producing thermal reactions include:





Pyrolysis is essentially the opposite of waste incineration, reflecting that the pyrolysis of waste is an endothermic process, while incineration is an exothermic process. Under the condition of low temperature and low heating rate, the organic molecules in the material have enough reaction time to store heat, decompose at their weak bonding points, and then recombine into substances with strong thermal stability, and these substances will not easily change with the rise of pyrolysis temperature because of their strong stability. Under the condition of high temperature and high heating rate, the organic molecular structure in the material is completely broken, and then the low molecular organic matter is formed. The pyrolysis process of plastic waste has three main stages:

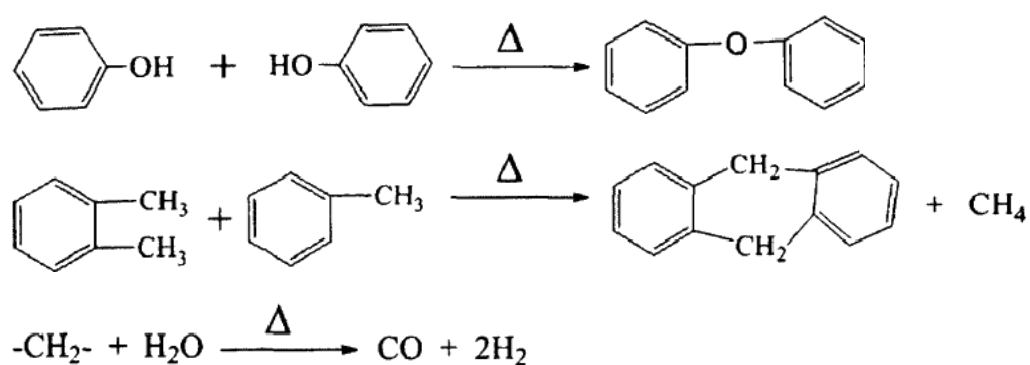
(1) In the drying degassing stage ($<300^\circ\text{C}$), the plastic morphology in the pyrolysis furnace has not changed in the temperature range below 300°C . Evaporation of water in domestic plastic waste occurs in the drying stage before 120°C ; Waste material pyrolysis products such as CH_4 , CO_2 , N_2 and other gases are released at around 200°C . At about 250°C , deoxygenation and desulfurization are carried out, in which the bound water splits with carbon dioxide, metabolic degradation occurs, and hydrogen sulfide splits in large quantities.

(2) Active thermal decomposition stage ($300^\circ\text{C} \sim 600^\circ\text{C}$) In this

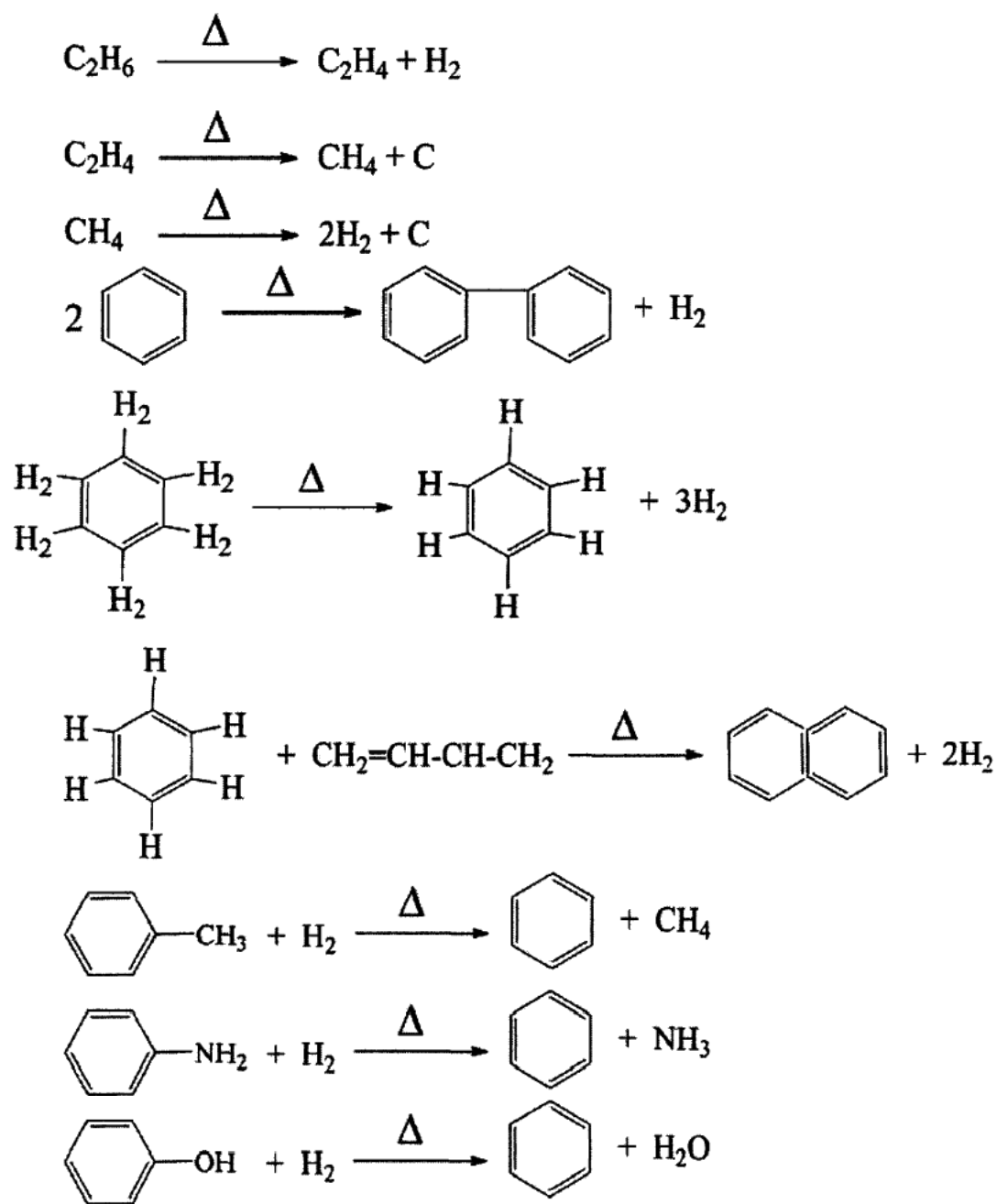
temperature range, a series of reactions will occur in the waste material to produce a large number of gaseous products, liquid phase and solid phase of the coexistence of colloidal body. Around 380°C, it enters the carbonization stage and begins to enrich a large number of carbon substances. When pyrolysis enters 400°C, C-O and C-N bonds in the substance begin to break.

(3) The secondary degassing stage (600°C~1000°C) In this stage, the coke produced in the previous active thermal decomposition stage produces a large amount of H₂, and the structure of the aromatic ring carbon network continues to form a compact and dense coke. The secondary cracking of coke and tar produces stable substances such as gas and short chain hydrocarbons. The olefins are polymerized into butene, dehydrogenated into butadiene, and the aromatics are converted into gasoline and high-boiling aromatics.

The reaction of water generation and the decomposition of the methylene-chain of the bridge part in the above three stages is as follows:



The resulting aromatic compounds began to decompose, dehydrogenate, condense, and hydrogenate to form CH₄, NH₃, and H₂O. The reactions were as follows:



As one of plastic waste treatment technologies, pyrolysis technology has been widely concerned at home and abroad because of its advantages of low pollution emission. However, the composition of plastic waste is complex and uneven, and the gases released during the pyrolysis process will release some harmful gases that cause direct or indirect pollution to the atmospheric environment in addition to the main calorific value gases that can be recycled.

Depending on their nature, these pollutants can be classified as organic pollutants, particulate matter, acid gases, etc. Typical pollutants released in the pyrolysis process of plastic waste include nitride, sulfide and so on.

Pyrolysis technology, as one of the plastic waste treatment technologies, occupies a unique position in the field of environmental protection. Because of its significant advantages of low pollution emissions, it has been widely concerned by many environmental activists, scientific research institutions and related enterprises at home and abroad. When the world is actively seeking more environmentally friendly and more efficient plastic waste treatment solutions, pyrolysis technology has undoubtedly become one of the focuses.

However, the characteristics of plastic waste itself pose a great challenge to pyrolysis technology. The composition of plastic waste is extremely complex, and the heterogeneity of different sources and different types of plastic waste in composition is very prominent. When these complex and heterogeneous plastic wastes are pyrolyzed, a variety of gases are released. Among them, although there are mainly calorific value gases that can be recycled, these calorific value gases can be further utilized to achieve the recovery and reuse value of energy. However, at the same time, there will also be some harmful gases produced. Once these harmful gases are discharged into the atmosphere, they will cause direct or indirect pollution.

From the point of view of the nature of pollutants, these pollutants can be divided into different categories, such as organic pollutants, particulate matter,

acid gases, etc. In the typical pyrolysis process of plastic waste, pollutants such as nitrides and sulfides are released. Nitride may undergo a series of complex chemical reactions in the atmosphere, forming environmental hazards such as acid rain and photochemical smog, affecting soil pH and vegetation growth. Sulfide will have a serious impact on air quality, resulting in a decline in air quality, endangering human respiratory health, but also will cause damage to the surrounding ecological environment, affecting biodiversity. The existence of these pollutants undoubtedly puts forward higher requirements for the further optimization and improvement of pyrolysis technology

The characteristics of pyrolysis technology make it attract a lot of attention as a kind of solid waste resource technology with great development prospect. The H_2 , CO, CO_2 and hydrocarbon components contained in pyrolysis gas are the key to evaluate whether pyrolysis gas has a high recovery rate. In recent years, the researches on pyrolysis technology at home and abroad mainly focus on the influence of pyrolysis conditions such as temperature, heating rate, catalyst and atmosphere on the composition of pyrolysis gas. However, the composition of urban plastic waste is complex and the structure is uneven, and the gases generated during the pyrolysis process also contain some harmful gases that cause pollution and damage to the environment and equipment, such as chloride, ammonia nitrogen, sulfide, etc. Qualitative research on the pollutants during the pyrolysis of urban solid waste has shown that the typical pollutants released are NH_3 and NH_2 . S. Figure 2-17 shows the company's plastic waste disposal system.

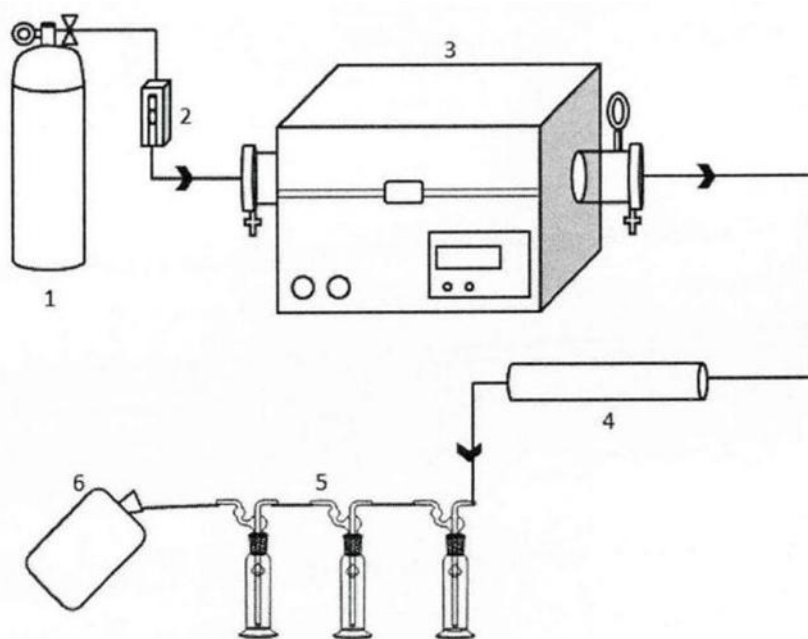


Fig 2.17 Diagram of the pyrolysis unit for municipal plastic waste

1 - Nitrogen cylinder; 2 - Flow meter; 3 - Horizontal tube furnace; 4 - Condensation unit; 5 - Absorption bottle; 6 - Gas bag

☐ Pyrolysis atmosphere conveying system

The pyrolysis reaction needs to be carried out in an oxygen-free and anoxic environment. The pyrolysis atmospheres commonly used in experiments include nitrogen, helium, argon, carbon dioxide, etc. In order to ensure that the pyrolysis experiment is carried out in an oxygen-free environment, nitrogen is selected as the thermal hydrolysis atmosphere in this study. As shown in Figure 2.1, the high-purity nitrogen (99.99%) in the cylinder is simultaneously transported to the entire pyrolysis furnace unit as the pyrolysis carrier gas, and the gas generated by the pyrolysis of MSW is purged to the absorption device along with the nitrogen carrier gas.

☐ Flow meter

The flowmeter used is a rotameter, which is used to control the purge flow rate of nitrogen and keep the gas flow rate in a stable range during the whole pyrolysis process. Before the pyrolysis of municipal solid waste, the nitrogen flow rate was controlled at 0.5L/min, so that the air in the reaction zone of the pyrolysis furnace was completely emptied, and the gas flow rate of the rubber hose in the absorption bottle was observed to be stable. When the pyrolysis reaction begins, the nitrogen flow rate is controlled at 0.35L/min.

□ Horizontal tube pyrolysis furnace

The pyrolytic furnace used in this paper is a fixed bed horizontal tube pyrolytic furnace. The pyrolytic furnace includes a temperature control panel area, a horizontal quartz tube reaction area (which also includes a quartz boat, quartz cotton and valves), and a pressure gauge. ①. The temperature control panel is used to set the programmed heating process of the pyrolysis reactor. Before the pyrolysis began, the initial pyrolysis temperature was set at 30°C, the heating rate at 10°C/min, and the final temperature at 600°C, 700°C and 800°C, respectively, and the final temperature was maintained for 20min.

The oil, gas and carbon black generated by the pyrolysis of plastic waste are all resources of high value, so the pyrolysis treatment method stands out among many waste plastic waste treatment methods and is called the ultimate treatment [64]. By studying the theory of electromagnetic induction heating and the characteristics and mechanism of the thermal decomposition of the typical components of waste plastics, it is considered that the pyrolysis equipment is the

place where the pyrolysis reaction occurs, which directly affects the pyrolysis temperature, heating rate, residence time and other key factors of waste plastics cracking, and ultimately determines the product quality.

According to the above theoretical data, the design principles of the company's equipment:

Cracking equipment is the place where cracking reaction occurs, is the most important part of the whole cracking process, how to achieve a good cracking process, to achieve the complete cracking of waste plastics, effectively eliminate secondary pollution, and commercial application is the ultimate purpose of cracking device design. Limited by the level of technology and the limitations of cracking devices, there is still no successful solution to meet the market demand. Comprehensive consideration of the factors affecting the cracking effect can be summarized as follows:

(1) Reliability during operation. The cracking device generally needs to operate at high temperature for a long time, so the stress and deformation of the cracking device must be considered when it is subjected to high temperature. Materials with high temperature resistance, high strength, good magnetic conductivity and excellent heat transfer are selected as the materials of the reaction device.

(2) To have excellent tightness. The high temperature and high pressure gas is easy to leak in the cracking equipment, which will not only affect the yield of the product, but also leak into the air and cause secondary pollution to the

environment, and even cause explosion accidents.

(3) Ensure the thermal insulation performance of the equipment. The cracking of waste plastic is carried out at a high temperature, so the cracking chamber must reach a very high temperature. If there is no insulation, a large part of the heat will be lost to the air, resulting in serious energy waste, and the high-temperature cracking device is more likely to pose a threat to human safety.

(4) Ensure uniform temperature distribution. The uniform heating of plastics by cracking equipment can increase the yield of liquid products and improve the quality of oil products. It can effectively reduce the occurrence of secondary reaction and coking of cracking cavity wall, and avoid over-cracking of plastics.

(5) With stable transmission capacity. The plastic is transformed from solid state to viscous flow state under high temperature heating, and the transmission capacity of the cracking equipment directly affects the retention time of the plastic in the cracking chamber and then affects the cracking effect.

(6) Good coil adaptability. The heating part of the pyrolysis experimental device includes inductor coil and controller. The design of induction coil is the key to the heater of the pyrolysis device. The effective length and turns of induction coil directly determine the heating effect, and the heating effect directly affects the cracking effect of plastic waste.

Equipment design scheme:

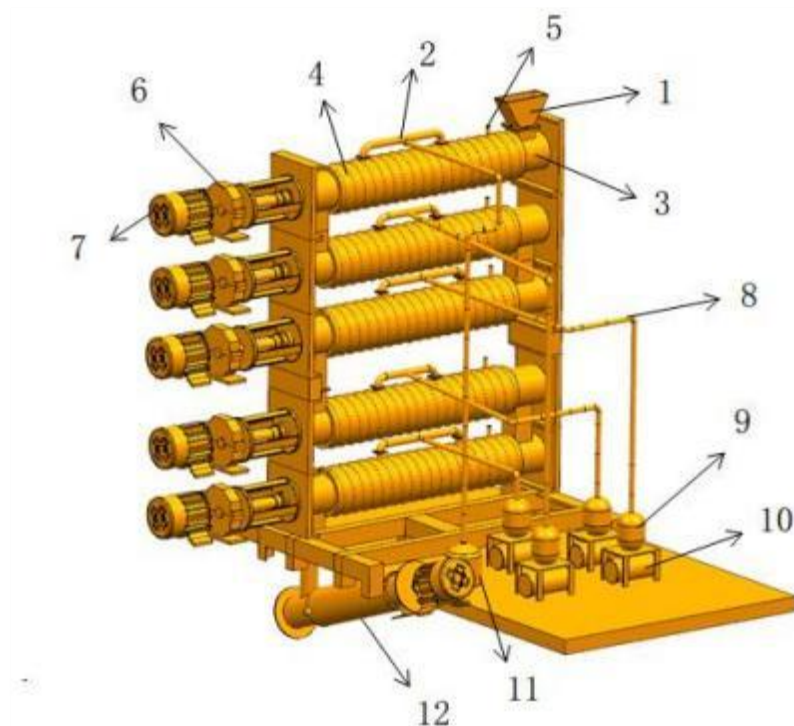
The pyrolysis of typical components of waste plastics was studied and

related literature was reviewed. The following design scheme is adopted: (1) The structure of the waste plastic cracking device mainly includes: feeding part, heating cracking part, cracking oil and gas recovery part, and solid residual transportation part. (2) For the hopper, the design of the upper generous mouth shrinking down to the bottom small square mouth. When the equipment is working, the way of large feed and small discharge is formed, and the material slips from the upper part to the lower part under its own weight, and the seal is automatically formed. (3) For the heating cracking part, the heating part is a total of five sections, the five sections are connected at the end and end, and the five sections all use cylindrical steel pipes as the reaction chamber for plastic cracking. In order to effectively prevent heat loss, ceramic fibers are tightly wrapped outside the cylindrical steel pipes as the thermal insulation layer. The heating method adopts the principle of electromagnetic induction heating, and the inductance coil is wound on the outer surface of the insulation layer. For the transportation of plastic in the steel pipe, the internal spiral push method is used. (4) The cylinder steel pipe is used as the reaction chamber for plastic cracking. In order to effectively prevent heat loss, the ceramic fiber is tightly wrapped outside the cylindrical steel pipe as the thermal insulation layer. The heating method adopts the principle of electromagnetic induction heating, and the inductance coil is wound on the outer surface of the insulation layer. For the transportation of plastics in the steel pipe, the built-in spiral is used. (5) In the solid residual transportation part, the way of the cutter push is used. The part is connected with the outlet of the bottom layer

of the cracking body into a inclined arrangement, and the circulating water cooling system is set outside, which not only automatically seals the material but also effectively reduces the temperature of the cracked residual carbon black and facilitates collection. (6) Each layer of the cracking body is equipped with temperature and pressure sensors to detect the real data at any time. Then adjust the operation in time.

Design of cracking equipment - overall design of cracking equipment

The whole equipment includes: feed hopper, five heating sections, carbon residue output section and oil and gas recovery system. The cylindrical cracking chamber is equipped with a spiral, each section is configured with a servo motor and a reducer, and each section is also provided with an air outlet, and the oil and gas are imported into the condenser through the pipeline and then condensed and collected. The waste plastics enter from the feed port, and the spiral in the cracking chamber pushes the material forward under the drive of the motor. At the same time, the electromagnetic coil heats the cracking chamber, and the waste plastics are heated while moving in the cracking chamber, pushing the material from never cracking to complete cracking. The bottom cracking section is connected with the slag discharge section, and finally the waste carbon black residue is discharged from the slag discharge port [65]. See Figure 2-18



1 inlet, 2 outlet, 3 cracking chamber, 4 insulation layer, 5 temperature sensor, 6 reducer, 7 motor, 8 oil and gas pipeline, 9 condenser, 10 oil storage tank, 11 gas tank, 12 slag discharge section

Fig.2-18 Whole assembly drawing of segmented waste plastic electromagnetic heating cracking experiment equipment

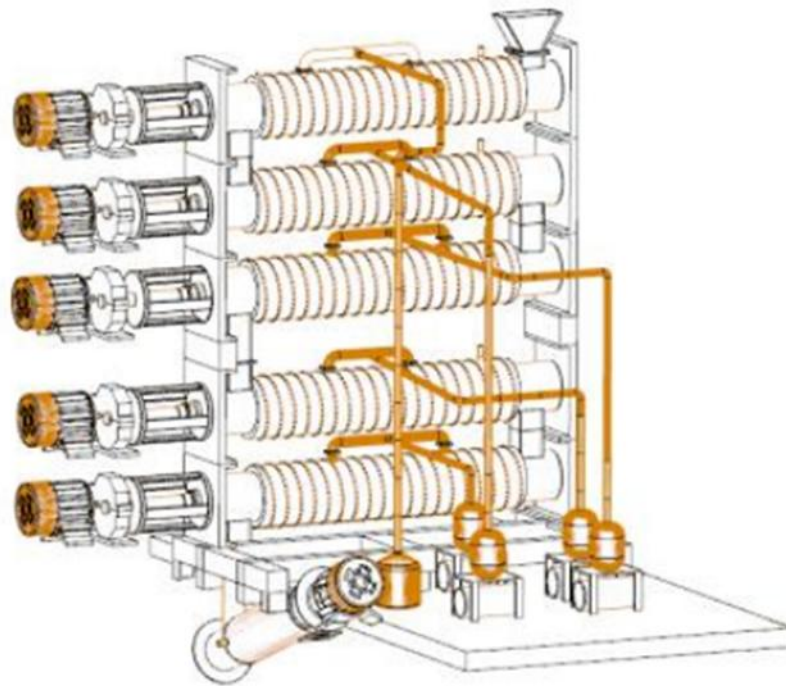


Fig.2-19 Three-dimensional line drawing of the experimental equipment for electromagnetic heating cracking of segmented waste plastics

□ Structure design of cracking chamber

The cracking chamber is the place where the cracking reaction of waste plastics occurs. The use of materials, the structure of the chamber and the size and location of the air outlet will have an important impact on the cracking effect, such as the impact on the cracking efficiency, heat transfer coefficient and gas velocity rate. The design scale of this design is for small laboratories. Considering the above influencing factors, the structure of the cracking chamber can be designed as follows: The whole adopts cylindrical steel pipe with inner cavity diameter D of 125mm, wall thickness s of 10mm and length L of 1000mm, which is supported at both ends. Two air outlet pipes with a diameter of $d=20\text{mm}$ and a height of $h=30\text{mm}$ from the surface of the cavity are arranged at the positions 275mm and

400mm away from the fixed support end, and the total air outlet diameter is also $d=20\text{mm}$. The material was selected as 316L alloy steel for engineering. The three-dimensional structure of the cracking reaction chamber is shown in Figure 2-20:



Fig.2-20 3d drawing of the cracking chamber

Simulation analysis of cavity:

The analysis flow of steady-state thermal coupling with structure is established by finite element simulation software, and then the structure diagram of cracked cavity created by 3D mapping software UG is directly imported into Geometry. The established analysis process is as follows:

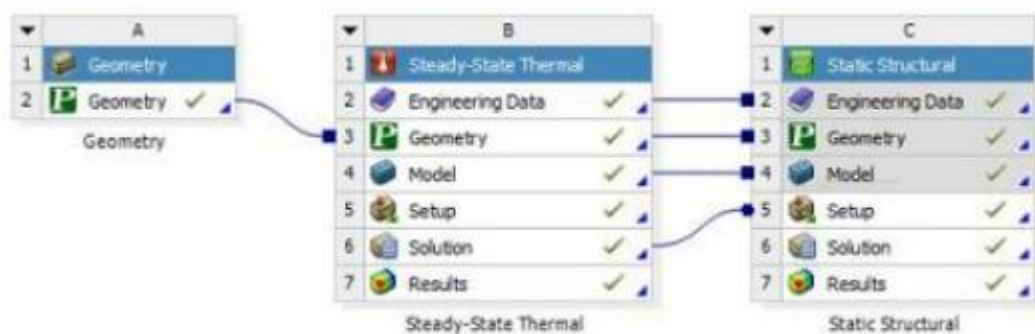


Fig.2-21 Flow chart of steady-state thermal-structure coupling simulation

Set the cavity material. Select 316L alloy steel from Workbench software material library and set it as the cavity material, then select Mesh to mesh the cracked cavity and set the mesh size to fine. Figure 2-22 shows the partition result

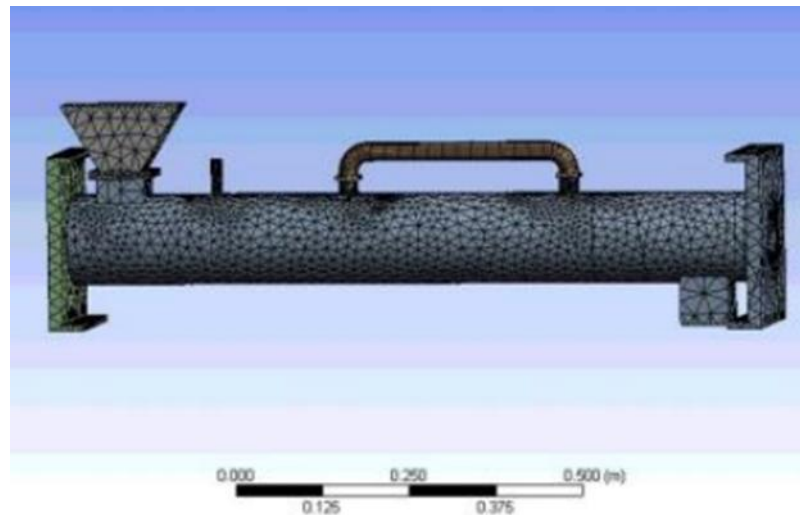


Fig2-22 Cracking cavity meshing

A temperature load is applied. According to the thermogravimetric experiment, the maximum temperature for the cracking of various waste plastics is generally 500°C . In order to ensure normal and stable operation at this temperature, a temperature load of 600°C is applied to the outer surface of the cracking chamber for heat transfer and stress analysis.

Result post-processing. After the Solution is completed, the temperature distribution, stress, and total deformation cloud maps as shown in Figure 2-23, 2-24, and 2-25 are obtained.

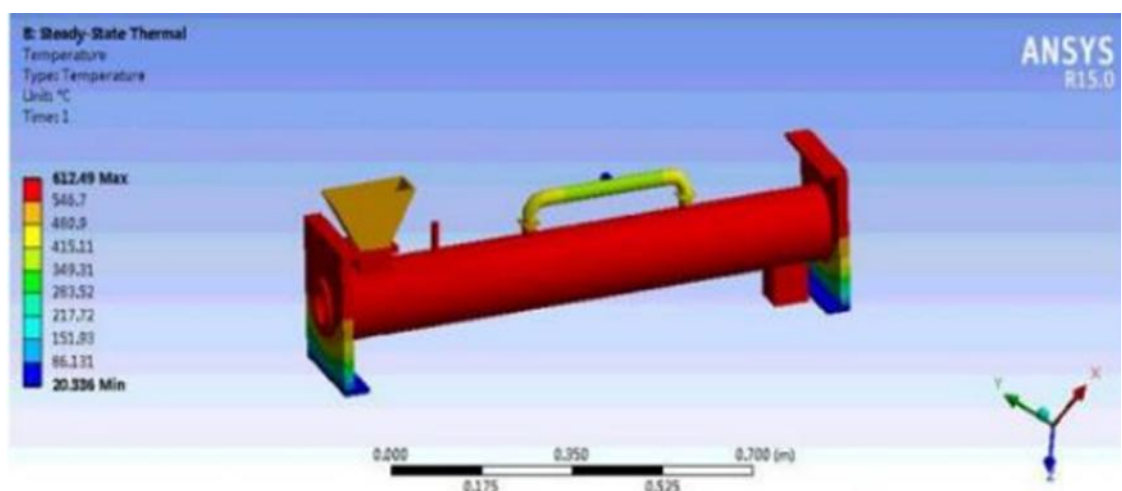


Fig.2-23 Cracking chamber temperature distribution

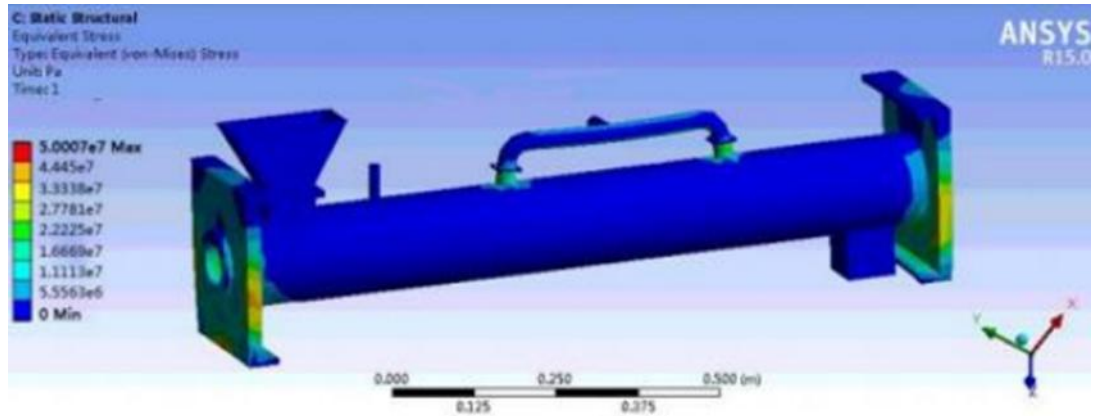


Fig.2-24 Stress diagram

It can be observed from the general deformation diagram that both axial and radial thermal deformation occur in the cracked cavity. The stress on both ends of the cracking chamber is large, and the stress is concentrated in the radial direction. Due to the asymmetric design of oil and gas pipelines, the thermal expansion amount is inconsistent, so the symmetrical design can be considered. The temperature cloud map also shows that the temperature inside the cracking chamber can meet the temperature requirement. Relevant literature records that the allowable stress of 316L alloy steel at 700℃ is 83MPa, so the allowable stress at 600℃ should be greater than this value, and the observation of stress cloud map shows that the maximum stress of the cracking chamber is $\sigma = 50\text{MPa}$, less than 83MPa, so the design meets the requirements.

Screw design

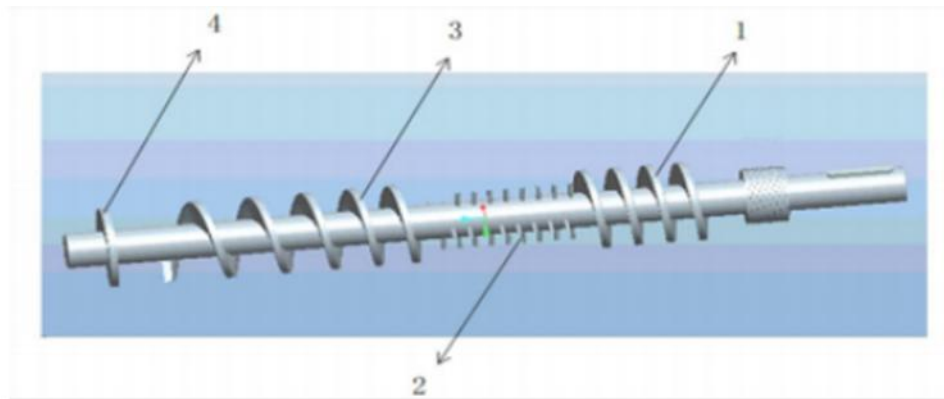
The screw plays a key role in the continuous transport and agitation of the plastic so that the plastic is uniformly heated. The change of material state occurs in the plastic high-temperature state, from the solid particles to the viscous flow state by heating and melting, which increases the difficulty of plastic

transportation, if the plastic can not be effectively transported in the cracking chamber, it will increase the residence time in the cracking equipment, resulting in over-cracking. Secondly, while pushing the material, the material should be fully stirred to make it evenly heated. Taking these factors into account, the screw is designed into four structures along the axis:

1) the screw includes a first screw part, a needle rolling part, a second screw part and a reverse screw part, and the pitch of the first screw part is less than the pitch of the second screw part, and the needle rolling is four rows and the radial of each row is 90° . Design helix diameter $\phi = 60\text{mm}$, outer diameter of the circular helix plate is $D = 120\text{mm}$, total length $L = 1100\text{mm}$, pitch of the first helix $S_1 = 40\text{mm}$, pitch of the second helix $S_2 = 60\text{mm}$, needle rolling spacing 15mm , diameter $d = 8\text{mm}$. The reverse spiral blade is arranged 100mm away from the second spiral part. Figure 5-10 shows the structure.

2) The first screw part pushes the material, because the first screw part has a smaller pitch, it pushes the material forward at a faster speed to ensure the efficiency of continuous feeding; The material is pushed to the needle rolling part, because the needle rolling part has no spiral Angle, the material in this position can ensure a long time continuous shearing and stirring to make the material fully mixed and heated; Due to the continuous feeding and the continuous advancement of the first screw part, the needle roller part will continue to push the material to the second screw part when the material is full to a certain extent. Because the pitch of the second screw part is larger than that of the first screw part, it will push

the material forward at a lower speed to ensure the heating and cracking time of the material. Finally, impurities such as carbon black will continue to be transported forward to the reverse screw position. Ensure that the residues fall smoothly into the collector for collection [66]. Figure 2-25 shows the structure of the spiral axis.



1 First screw part, 2 needle rolling part, 3 second screw part, 4 reverse screw part

Fig.2-25 Three-dimensional design of the structure of the spiral axis

Spiral check

In the same way, the thermal structure coupling process was established, the model was imported into the material of 316L alloy steel, the mesh was divided and the loading temperature was analyzed, and the stress and deformation of the spiral at high temperature was analyzed. Due to the heat transfer from the cracking cavity to the spiral from the outside and inside, a temperature load is applied to the blade edge of the spiral, and a temperature load of 600°C is also applied to the spiral in order to meet the strength requirements. The stress distribution and deformation nephograms of the spiral are shown as 2-26, 2-27.

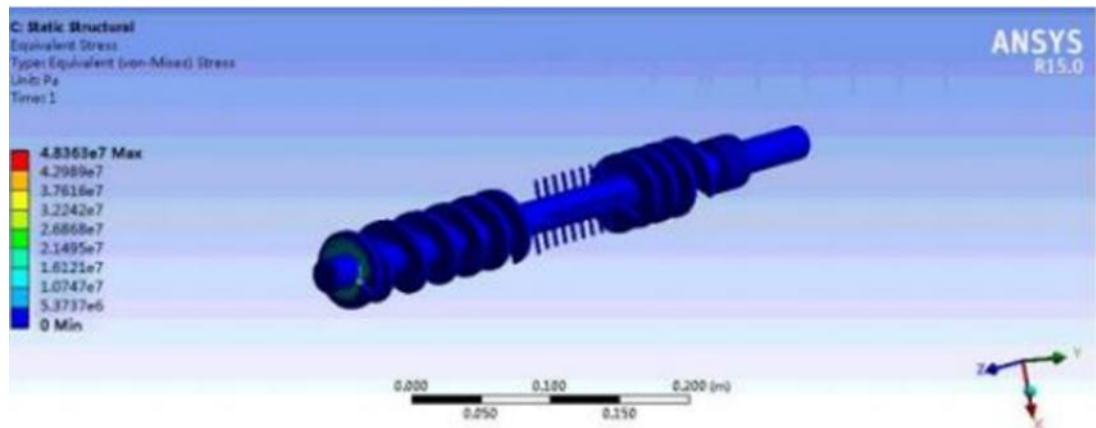


Fig.2-26 Stress diagram

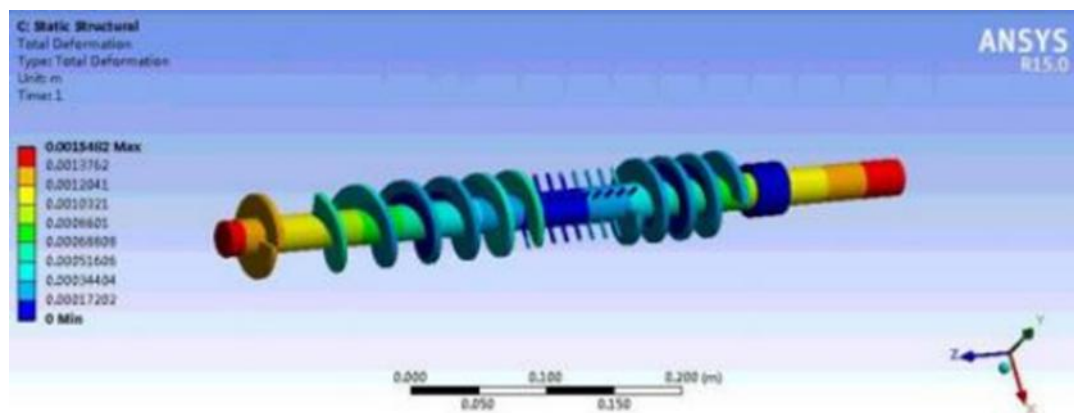


Fig.2-27 Total deformation diagram

It can be seen from the observation of the cloud image that the deformation mainly occurs at the end, the deformation amount is 1.5mm, and the gap between the screw and the barrel is designed to be 2mm to meet the working requirements. The allowable stress of metal material 316L alloy steel at 700℃ is $\sigma = [83]\text{MPa}$. As can be seen from the stress cloud map, the spiral stress $\sigma = 48.4\text{MPa}$, similarly less than the maximum allowable stress, also meets the design requirements.

Thermal insulation of equipment

Ceramic fiber products refer to ceramic fiber as raw materials, because of light weight, high temperature resistance, good thermal stability, low thermal conductivity, low specific heat, mechanical vibration resistance and other

characteristics and are widely used in various industrial products. Designed for high pressure, easy to wear environments. According to the relevant literature, it can be known that ceramic fibers can withstand high temperatures of about 1000 ° C, and the pyrolysis temperature of waste plastics is 400-500 ° C, so ceramic fibers can be applied to the thermal insulation device of waste plastic cracking reaction, and only the ceramic fibers need to be located on the outer surface of the reaction chamber. The thickness of the ceramic fiber insulation layer used in the design of this equipment is $h=15\text{mm}$. Figure 2-28 shows the ceramic fiber material.

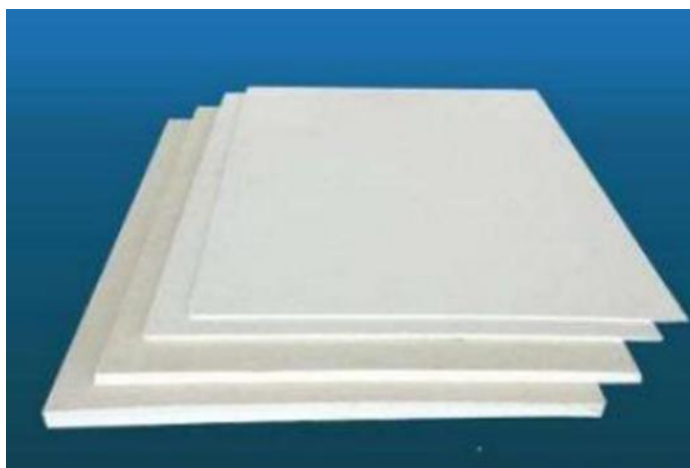


Fig 2-28 Ceramic fiber

Recovery portion

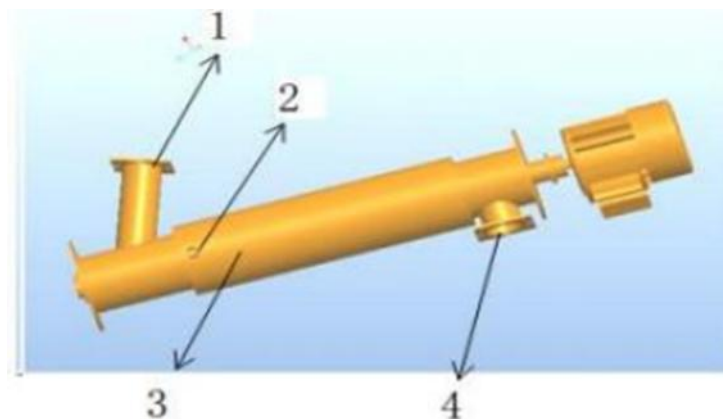
Cracking oil is one of the important products of waste plastic cracking. The waste plastic is decomposed at high temperature in the cracking chamber, but it not only produces oil and gas, but also changes the water in the waste plastic into water vapor. As mentioned earlier in this paper, the thermal cracking process of chlorine-containing plastic PVC is divided into two parts, the first is the removal of HCl gas, and then the fracture of large molecular chains into small molecules,

and then the generation of oil and gas. The five cracking cavities in this scheme are all connected with gas delivery pipes, as shown in Figure 2-X. The specific recovery process of cracked oil and gas is: each stage of the removed material is collected separately. Toxic gases such as water and HCl are produced from the thermal decomposition of the mixed waste plastics in the first, second and third stages, and are removed by the collection tank equipped with alkaline substances. A small part of the oil and gas is condensed by their respective condensers for oil collection, reducing the moisture content of subsequent cracking oil and the corrosion of toxic acidic gas to the cracking equipment. In the fourth stage, the mixed waste plastic will undergo the main thermal cracking, most of the waste plastic cracking is completed, and the resulting cracked oil and gas is introduced into the condenser and then collected. The specific recovery process of cracked oil and gas is: each stage of the removed material is collected separately. Toxic gases such as water and HCl are produced from the thermal decomposition of the mixed waste plastics in the first, second and third stages, and are removed by the collection tank equipped with alkaline substances. A small part of the oil and gas is condensed by their respective condensers for oil collection, reducing the moisture content of subsequent cracking oil and the corrosion of toxic acidic gas to the cracking equipment. In the fourth stage, the mixed waste plastic will undergo the main thermal cracking, most of the waste plastic cracking is completed, and the resulting cracked oil and gas is introduced into the condenser and then collected.

In the fifth section, the residue of the mixed waste plastic that has not been cracked is completely cracked, and the oil and gas generated by it is collected after condensation and heavy oil products. The produced non-condensing gas is reprocessed to obtain combustible gas for daily use. This process can achieve the automatic classification of light and heavy oil products to a certain extent, improving the value of oil products.

Carbon residue discharge part

The product of plastic cracking includes not only cracking gas but also cracking carbon, and the cracking carbon collection device is also an important part of the cracking equipment. The pyrolysis carbon temperature is very high, but also consider the issue of outlet sealing, so the design of the residual carbon discharge part of the use of variable pitch spiral structure, so that the residual carbon is compactized and promoted to ensure safe sealing. The residual carbon discharge device is installed at a certain Angle, the discharge port is higher than the bottom of the feed port (to play the role of automatic material sealing), and the circulating water is used to cool down, and the water flows into the high-end from the low end. Reduce the temperature of cracked carbon residue and reduce the risk of workers collecting carbon residue [67]. Figure 2-29 shows the structure.



1 carbon black inlet, 2 cold water inlet, 3 cold water jacket, 4 slag outlet

Fig.2-29 Carbon black export device

The cracking mechanism of the vast proportion of PVC, PP, PS, ABS, PE single products and mixed plastics. The proportion of five kinds of waste plastics and the mixture of five kinds of waste plastics in the actual domestic plastic waste samples were prepared, and the thermogravimetric experiment (TG) or differential scanning calorimetry (DSC) experiment was carried out. Set different heating rates (10-90 °C)/min. It is observed from the experimental data that: (1) With the increase of the heating rate, the thermogratings of the typical components of waste plastics PP, PE, PVC, PS and ABS all show a hysteresis phenomenon. (2) The thermal stability sequence of the typical components of waste plastics is: PP > ABS > PS > PE > PVC, and the maximum cracking rate is PE > PS > PP > ABS > PVC. (3) Under the condition of a heating rate of 10 °C/min, the temperature of PVC dechlorination completion is 318.5 °C, while the initial cracking temperature of other waste plastics is greater than this temperature, proving that the cracking of other plastics begins after the completion of dechlorination, and there is no crossover between the dechlorination process and the cracking temperature

segment of other waste plastics. (4) The thermal cracking time analysis of the typical components of waste plastics PP, PE, PVC, PS and ABS obtained the time required from the cracking start to the cracking completion: The whole pyrolysis weight loss process of PP, PE, PS and ABS is about 10min, the severe thermal weight loss time is 3.7 minutes for PP, 3.4 minutes for PE, 3.4 minutes for PS, and 4.8 minutes for ABS. PVC plastic is heated from room temperature to about 265 ° C to begin dechlorination until 318.5 ° C dechlorination is completed, during which a total of about 30 minutes is needed, from the completion of dechlorination to complete cracking takes 16 minutes. (5) The activation energy and pyrolysis mechanism of ABS, PS and the actual proportion of mixed plastics were obtained. The pyrolysis kinetic parameters obtained by the three equations have guiding significance for the pyrolysis of single waste plastic components and mixed waste plastics. (6) Through the exploration of the pyrolysis process of PVC, PP, PS, ABS and PE waste plastics, a new type of plastic waste treatment method - segmented waste plastic cracking is proposed. A new experimental device for continuous cracking of plastic waste by electromagnetic heating was designed and checked.

Chapter 3 DIFFICULTIES ENCOUNTERED BY THE COMPANY AND MEASURES

3.1 Technical Challenges

In the field of plastic waste treatment, the technical challenges are multifaceted, involving classification accuracy, treatment efficiency, environmental impact and other levels. Here is a detailed analysis of these challenges and what can be done about them.

☐ Balance of precision and efficiency

In the automatic sorting process of plastic waste, achieving a balance of high accuracy and high efficiency is indeed a technical challenge. Although the current system has been able to achieve 95.8% classification accuracy, which is quite impressive in the industry, but in the face of complex and diverse plastic waste, the system's classification ability is still facing a severe test. Especially when dealing with film plastics, such as plastic bags and food packaging, because these materials are thin and transparent, they are easily confused with the background or other substances in the image recognition process, resulting in recognition difficulties. This property of thin film plastics makes their identification and classification in automatic classification systems a particularly tricky problem.

The size diversity and uneven thickness of thin film plastics further increase the complexity of classification. These materials may have very different sizes and thicknesses in different application scenarios, which affects the classification

system's ability to recognize them. For example, differences in the physical properties of a thin plastic bag and a thick food packaging film can cause the same classification system to identify them very differently. In addition, thin-film plastics may become wrinkled or stick during transportation and handling, further interfering with the visual recognition module of the classification system.

Dark plastics, especially black plastics, are difficult to be accurately identified by traditional optical recognition techniques due to the characteristics of their color absorption spectra. This absorption property causes dark plastics to lack sufficient reflection in visible light, making their features in the image not distinct enough to be captured and distinguished by the classification system. In addition, dark plastics may exhibit inconsistent reflection characteristics under different lighting conditions, which further increases the difficulty of identification for classification systems.

In order to solve these problems, it is necessary to improve and innovate the existing classification technology. This could include developing new image processing algorithms to better handle the transparency and size diversity of thin film plastics; The use of advanced spectral analysis technology to overcome the challenges of optical identification of dark plastics; And the use of machine learning technology, through a large number of data training, improve the system's ability to identify these complex plastic waste. In addition, it is possible to consider the introduction of multimodal sensing technology, combining multiple sensor data such as vision, touch, and spectrum to achieve more accurate classification.

□ □ Harmful gas emission

In the pyrolysis process of plastic waste, due to the complex composition of plastic materials and chemical reactions in the pyrolysis process, a variety of harmful gases will be produced. The emission of these gases poses a serious threat to the environment and human health, and has become a key problem to be solved urgently in the field of plastic waste disposal. The sources, effects and control measures of these harmful gases are discussed in detail below.

Hydrogen chloride (HCl) Hydrogen chloride is a colorless gas with pungent odor. In the pyrolysis treatment of plastic waste, its main source is the pyrolysis process of chlorine-containing plastics, especially polyvinyl chloride (PVC). During the pyrolysis of PVC, chlorine atoms in it will combine with hydrogen atoms to form HCl gas and be released. HCl is highly corrosive and, when released into the atmosphere, reacts with water vapor to form hydrochloric acid. Such acidic substances fall to the ground with precipitation, which will cause soil acidification, change the pH of the soil, and then affect the absorption of nutrients by plants, inhibit the growth of plants, and destroy the ecological balance. At the same time, HCl will also cause pollution to the water body, make the acidity of the water body increased, and endanger the living environment of aquatic organisms. In terms of the impact on human health, HCl has a strong stimulating effect on the human respiratory system. When people breathe in air containing HCl, it can irritate the respiratory mucosa, causing coughing, wheezing, chest pain and other uncomfortable symptoms. If long-term exposure to high concentrations of HCl in

the environment, it may even lead to respiratory tract burns, seriously damage the normal function of the respiratory tract, and pose a serious threat to human health.

Ammonia is a colorless gas with a strong pungent odor, and its main source in the pyrolysis of plastic waste is nitrogen-containing plastics or additives. In the pyrolysis reaction, nitrogen-containing substances undergo chemical reactions such as cracking and recombination, and are finally released in the form of NH_3 . In the atmosphere, ammonia can react with acidic substances to form particulate matter. These particles will be suspended in the air, reduce air quality, affect the visibility of the atmosphere, and have a negative impact on human health and the ecological environment. For the human body, ammonia is harmful to health and can cause respiratory problems. When the human body inhales ammonia, ammonia will irritate the respiratory mucosa, causing respiratory inflammation, leading to cough, breathing difficulties and other symptoms. In addition, ammonia also has a strong irritation to the skin and eyes, after contact with ammonia, the skin may appear red, swollen, itching and other discomfort, eyes will feel stinging, tears, and in serious cases may even cause damage to vision.

Hydrogen sulfide (H_2S) Hydrogen sulfide is a colorless, rotten egg odor highly toxic gas, mainly from the pyrolysis of sulfur-containing plastic additives. In the pyrolysis process, sulfur combines with hydrogen free radicals to form H_2S gas, which is analyzed as volatilization. Hydrogen sulfide itself is a strong neurotoxic, has a strong irritating effect on the human body. It can be inhaled through the respiratory tract and absorbed into the body through the skin, even a

low concentration of H₂S, can be detected by the body, and pose a threat to human health. When inhaled, hydrogen sulfide can cause serious health problems, such as breathing difficulties, headaches and nausea, and in high concentrations can even lead to coma and death.

□ Economic challenge

The plastic waste treatment industry is facing increasingly severe economic challenges around the world, which are like mountains across the road of enterprises and constitute a significant obstacle to the sustainable development of the industry. It involves a wide range of aspects, not only covering cost control and investment return period issues, but also to market competitiveness, fund raising, policy support and other key areas.

Cost control is undoubtedly the primary economic challenge faced by enterprises in the process of plastic waste disposal. With increasingly stringent environmental regulations and frequent fluctuations in raw material prices, companies are in the midst of a choppy sea and need to precisely navigate the "sailing boat" of costs under the dual pressure of ensuring treatment efficiency and environmental standards. The strengthening of environmental regulations means that companies must invest more money in equipment upgrades, technological improvements, and the implementation of environmental protection measures to ensure that their processing processes meet regulatory requirements. For example, companies may need to purchase more advanced waste gas treatment equipment to reduce harmful gas emissions, or improve wastewater treatment systems to

avoid causing pollution to the water body, these additional investments will undoubtedly increase the operating costs of the company. At the same time, the fluctuation of raw material prices has also brought great uncertainty to enterprises. As a raw material for disposal, the supply and price of plastic waste are affected by a variety of factors, such as changes in market demand, fluctuations in international crude oil prices, and the stability of the recycling system.

When the price of raw materials rises, the production cost of enterprises will increase, if the cost cannot be effectively passed on to the price of products or services, the profit margin of enterprises will be severely compressed. In addition, businesses need to find a delicate balance between processing efficiency and cost. Improving processing efficiency often requires more investment in technology research and development and equipment updates, but if the benefits of processing efficiency improvements cannot compensate for the increased costs, enterprises will be in a dilemma.

The return on investment period is also an important issue that enterprises must face. Plastic waste disposal projects usually require a large amount of upfront investment, including land purchase, plant construction, equipment procurement, and technology research and development. These large investments mean that companies need to recoup their costs and become profitable for a considerable period of time after the project is operational. However, due to factors such as fierce competition in the industry, changes in market demand and uncertainty in the policy environment, the investment return period is often variable. If the

investment return period is too long, the enterprise will face greater financial pressure, which may affect its subsequent development and expansion plans. In terms of market competitiveness, the plastic waste treatment industry is in a stage of rapid development, and the market competition is becoming increasingly fierce. Many companies have rushed into this field to compete for a limited market share. Enterprises not only have to compete with domestic counterparts, but also face strong rivals from the international market. In this competitive environment, enterprises need to continuously improve their core competitiveness, including technical level, service quality, brand influence and so on. For example, companies need to continuously invest in research and development resources to develop more efficient and environmentally friendly processing technologies to meet the increasingly diverse needs of customers; At the same time, it is also necessary to optimize the service process, improve the efficiency and quality of service, establish a good corporate brand image, and enhance customer loyalty. Financing is also a big challenge for plastic waste disposal companies.

If the policy changes frequently, it will be difficult for enterprises to formulate long-term development strategies, increasing the risk of business operation. The economic challenges facing the plastic waste treatment industry are multifaceted and complex, and it requires the joint efforts of enterprises, governments and society to promote the sustainable development of the industry through measures such as strengthening cost control, optimizing the return on investment period, enhancing market competitiveness, broadening financing

channels and increasing policy support.

□ Regulatory compliance

In the field of plastic waste disposal, policies and regulations play an important role in guiding and constraining. China has issued a series of laws and regulations on plastic pollution control, setting clear requirements and directions for the operation and development of enterprises.

The Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste, revised in 2020, makes clear provisions on the prevention and control of pollution by agricultural films, packaging materials, and disposable plastic products. For example, the production and sale of ultra-thin plastic shopping bags with a thickness of less than 0.025 mm and polyethylene agricultural mulch with a thickness of less than 0.01 mm are prohibited; A total ban on the import of waste plastics; By the end of 2020, prohibit the production and sale of disposable foamed plastic tableware, disposable plastic cotton swabs, and prohibit the production of daily chemical products containing plastic microbeads; By the end of 2022, the sale of daily chemical products containing plastic microbeads will be banned.

In January 2022, the "Measures for the Classification and Management of Municipal Solid Waste in Henan Province" was announced and officially implemented. Since January 1, 2024, the Provisions of Henan Province on Prohibiting and Restricting non-degradable Disposable Plastic Products have been officially implemented, and the provincial government has issued the List of

Prohibited and Restricted non-degradable Disposable Plastic Products in Henan Province. The regulations clearly prohibit and restrict the production, sale, use and related activities of some non-degradable disposable plastic products in the province, and prohibit and restrict the implementation of list management of non-degradable disposable plastic products. Specifically, the production and sale of ultra-thin plastic shopping bags with a thickness of less than 0.025 mm, polyethylene agricultural mulches with a thickness of less than 0.01 mm, disposable foamable plastic tableware, disposable plastic cotton swabs, daily chemical products containing plastic microbeads are prohibited, and the manufacture of plastic products using medical waste as raw materials is prohibited. By region, industry and stage, it is prohibited to restrict the use of non-degradable plastic bags, disposable plastic tableware, disposable plastic straws, disposable plastic products in hotels (hotels), and express plastic packaging. For example, in Henan Province, the implementation area is urban built up areas of cities at or above the county level, prohibiting the use of non-degradable plastic shopping bags for holding and carrying goods in shopping malls, supermarkets, bookstores, pharmacies, food packaging and takeout services, exhibitions and other places, but excluding for health and food safety purposes. Used for bulk fresh food, cooked food, pasta and other commodities plastic pre-bags, rolled bags, bags, etc.; Postal express outlets in Zhengzhou, Luoyang, Puyang, and Xuchang are prohibited from using non-degradable plastic bags, and by the end of 2025, the province's postal express outlets will prohibit the use of non-degradable plastic bags, plastic tape,

and disposable plastic woven bags.

It is critical for plastic waste companies to ensure that their operational processes and product characteristics fully comply with the latest regulatory requirements. With the increasing awareness of environmental protection and the increasingly severe global environmental problems, environmental laws and regulations are in the process of continuous updating and strengthening. Enterprises must establish a sound regulatory monitoring mechanism, arrange special personnel to pay close attention to the dynamic adjustment of environmental regulations, timely access to the latest information and in-depth interpretation. At the same time, these regulatory requirements are accurately integrated into the daily operation and product development process, which involves the adjustment of the production process, processing equipment, raw material screening, product quality standards and other aspects.

□ Market and competitive challenges

In the process of the vigorous development of the plastic waste treatment industry, the market and competitive challenges are like turbulent waves, constantly impacting the survival and development of enterprises. Enterprises must accurately understand the market dynamics, skillfully cope with competitive pressure, in order to break the waves in this choppy business sea. With the increasing attention of society to environmental protection and the rapid development of science and technology, plastic waste treatment technology has shown a rapid trend. This positive development trend, while injecting new vitality

into the industry, inevitably leads to increasingly fierce market competition. Many new enterprises with innovative technologies have sprung up in this field, with their unique technical advantages, flexible market strategies and keen capture of customer needs, to the existing enterprises in the industry posed a strong challenge.

Taking Guangdong Yuekong Electric Co., Ltd. as an example, under the current market pattern, it not only has to compete fiercely with those established domestic enterprises that have been deeply engaged for many years, have a solid foundation and have rich experience and broad market share in the field of traditional plastic waste treatment technology, but also be always alert to potential competitors from the international market. These international enterprises often have advanced technology research and development capabilities, mature business models and global market layout, they rely on their own advantages, trying to get a share of the vast and potential of the Chinese market.

□ □ Supply chain challenges

In the plastic waste treatment industry, the supply chain is like the lifeline of enterprise operation, and its stability and efficiency are directly related to the survival and development of enterprises. However, at present, the industry is facing many serious challenges in the supply chain, which are particularly prominent in the supply of raw materials and logistics, bringing great pressure to the normal operation of enterprises.

The plastic waste treatment industry is highly dependent on raw materials, and the stable supply of raw materials is the basis for the continuous production

of enterprises. However, the reality is that raw material market prices fluctuate frequently and supply is unstable, which has a profound impact on business operations. Raw material market price fluctuations are mainly driven by a variety of factors. On the one hand, the fluctuations of international crude oil prices have a significant impact on the price of plastic raw materials. Crude oil is an important basic raw material for plastic production, and its price fluctuations will be transmitted along the industrial chain, resulting in significant changes in the raw material procurement costs of plastic waste treatment enterprises. For example, when international crude oil prices rise due to geopolitical conflicts, changes in the global economic situation or production adjustments in oil producing countries, the price of plastic raw materials will also rise. This makes enterprises face great challenges in cost control. If the cost increase cannot be passed on to the price of products or services in time, the profit margin of enterprises will be severely compressed.

As the global trade environment continues to change, logistics costs continue to rise, putting heavy pressure on the profitability of plastic waste disposal enterprises. The change of global trade environment has many effects on logistics cost. In recent years, international trade frictions have intensified, trade policies between countries have frequently adjusted, and tariff barriers have increased, which makes plastic waste treatment companies face higher costs when purchasing raw materials or selling products across borders. For example, Fuhua industry imported a batch of special plastic additives from abroad, and the import

cost of this batch of raw materials increased by about 15% due to the increase in tariffs caused by trade friction. In addition, the global outbreak of the epidemic has also had a huge impact on the logistics industry. During the epidemic period, countries have taken lockdown measures to prevent and control the epidemic, which has hindered logistics and transportation, greatly reduced transportation efficiency and extended transportation time. At the same time, the epidemic has led to an increase in the labor costs of logistics enterprises, such as increasing the input of epidemic prevention materials to ensure the safety of employees, paying staff quarantine subsidies, etc., and these additional costs are ultimately transferred to logistics costs. In China, the strengthening of environmental protection policies has also had a certain impact on logistics costs. With the improvement of environmental protection requirements, logistics transport vehicles need to meet more stringent emission standards, which encourages logistics enterprises to speed up the replacement of vehicles and purchase new vehicles that meet environmental protection standards, thus increasing the purchase cost of transportation equipment. At the same time, some areas have adjusted the truck restriction policy, limiting the passage time and route of trucks, resulting in an increase in the time cost and operating costs of logistics transportation.

□ Technology renewal and personnel training

In terms of technological update, the technological development of the electrical industry is changing with each passing day, and new theories, materials and processes continue to emerge. Yuekong Electric Limited needs to keep up with

the pace of technological developments to ensure that its products and services remain competitive in the market. However, the high investment in research and development required to update the technology has put a huge pressure on the company's financial position. In addition, the research and development of new technologies often has a high risk, may face research and development failure, technical difficulties are difficult to overcome and other problems. At the same time, it takes time for the market to accept and recognize the new technology, which makes the company need to be more cautious in the decision of technology update.

The company has also struggled with talent development. First of all, with the continuous progress of electrical technology, the professional knowledge and skills of talents are increasingly required. The company's existing talent team has insufficient knowledge reserve and lagging skill update in some emerging technology fields. However, it is not easy to recruit high-quality talents with the latest technical knowledge and rich practical experience, and the competition for such talents in the market is very fierce. Secondly, retention of talent is also a key issue. The rapid development of the electrical industry makes the flow of talents more frequent, how to provide employees with attractive career development planning, good working environment and welfare benefits, in order to reduce the loss of talents, Yuekong Electric Co., Ltd. needs to focus on. Moreover, cultivating employees' innovation ability is crucial to the long-term development of the company, but it is not easy to create an innovation atmosphere and establish an

effective innovation incentive mechanism. Finally, the company's internal training system also needs to be further improved. Due to the rapid change of technology, it is necessary to continuously optimize the content and methods of training to ensure that employees can timely grasp the latest technology and knowledge, but this requires a large investment of time and resources.

3.2 Electrical diagram of a system for automated sorting and pyrolysis of plastic waste

According to the previous design theory, the following is the layout of this plastic waste automatic classification system and heat engine system, as shown in Figure 3.1.

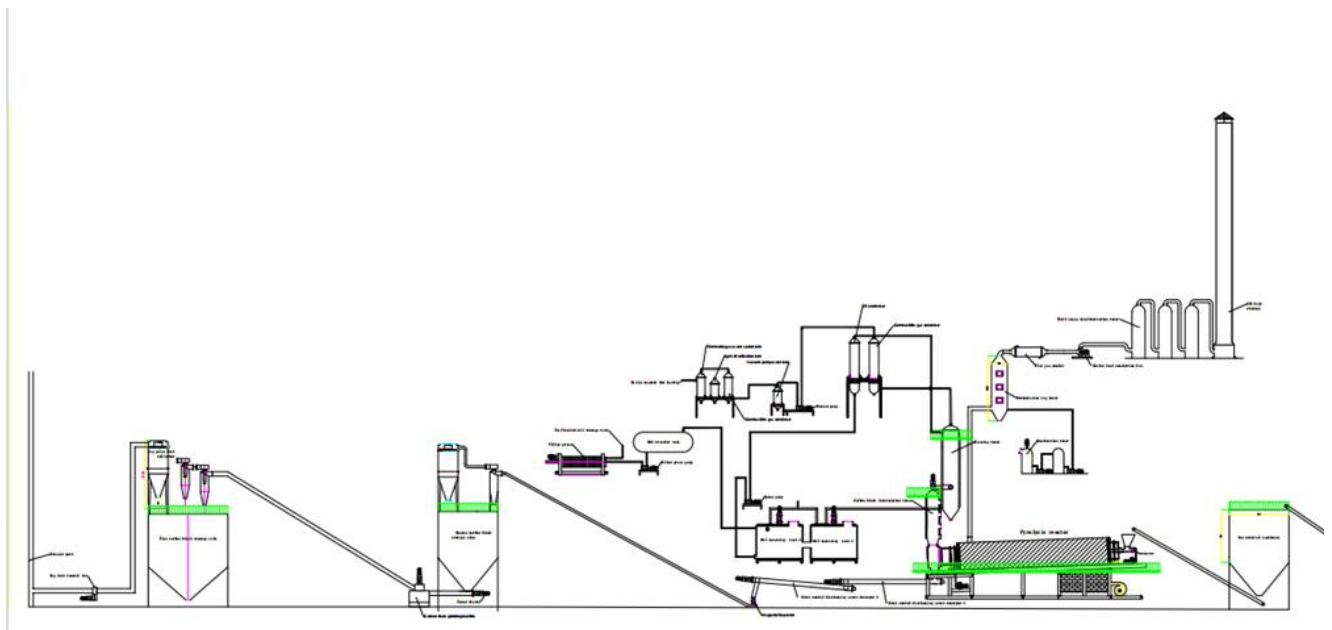


FIG. 3.1 Layout of plastic sorting system and pyrolysis system

The following is a detailed description of the machine layout of Guangdong Yuegong Electric Co., LTD. Plastic waste automatic sorting system and pyrolysis system:

I. Feeding Area

1. Feeding Hopper

- Located on the far left of the diagram, it is the starting point of the entire system. The feeding hopper is used to receive untreated plastic waste.
- The bottom of the feeding hopper is connected to an inclined conveyor

belt for smoothly transporting the plastic waste to the next processing stage.

II. Automatic Sorting Area

1. Primary Sorting Equipment

- The conveyor belt transports the plastic waste to the primary sorting equipment, which may include vibrating screens, magnetic separators, etc.

- The vibrating screens separate plastic particles of different sizes through vibration, and the magnetic separators are responsible for removing metal impurities mixed in the plastic waste.

2. Optical Sorting Equipment

- After primary sorting, the plastic waste enters the optical sorting equipment. These devices use optical sensors and image - processing technology to sort plastics based on characteristics such as color and transparency.

- The optical sorting equipment, through multiple conveyor belts and diverting devices, transports different types of plastics to different collection points.

III. Thermal Machinery System Area

1. Crushing and Grinding Equipment

- The sorted plastic waste enters the crushing and grinding equipment. These devices break larger plastic pieces into smaller particles for subsequent pyrolysis treatment.

- The crushing and grinding equipment usually consists of multiple crushers and grinders, connected by pipes and conveyor belts to ensure continuous

material processing.

2. Pyrolysis Reactor

- The crushed plastic particles are transported to the pyrolysis reactor.

The pyrolysis reactor is the core equipment of the thermal machinery system, usually a large - sized cylindrical tank.

- In an oxygen - free or oxygen - deficient environment, the pyrolysis reactor heats the plastics to cause pyrolysis reactions, decomposing them into small - molecule hydrocarbon substances.

- The pyrolysis reactor is equipped with heating devices, temperature control systems, and stirring devices to ensure that the pyrolysis reaction can be carried out efficiently and stably.

3. Product Separation and Collection

- The products generated by the pyrolysis reaction include gaseous, liquid, and solid substances. These products are collected and processed through different pipes and separation equipment.

- The gaseous products are converted into liquid oil through condensation devices, and the liquid oil is collected in storage tanks. The solid residues are transported to residue - processing equipment via conveyor belts.

IV. Auxiliary Equipment Area

1. Control System

- The entire system is equipped with an advanced control system, located near each key equipment in the diagram. The control system uses sensors

and actuators to monitor and control the operating parameters of the equipment in real - time.

- The control system ensures the stable operation of the equipment and promptly alarms and takes corresponding measures in case of abnormal situations.

2. Emission - treatment Equipment

- The exhaust gas generated during the pyrolysis process needs to be treated before being emitted. There is exhaust - gas - treatment equipment, including dust collectors, desulfurization and denitrification devices, etc., in the upper right corner of the diagram.

- These devices ensure that the emitted exhaust gas meets environmental protection standards and reduces environmental pollution.

V. Finished - product Processing and Storage Area

1. Liquid - product Storage

- The separated and processed liquid products, such as pyrolysis oil, are transported to liquid - product storage tanks. The storage tanks are usually large - sized metal tanks with anti - corrosion and heat - preservation functions.

2. Solid - residue Processing

- After further processing, the solid residues may be used as building materials or for other industrial purposes. There are solid - residue - processing and storage equipment in the lower right corner of the diagram.

In the technical field of plastic waste treatment, the electrical diagram is a key component of the entire treatment system, which visually presents the

connection relationship and working principle of each electrical component in the system. For automatic plastic waste sorting and pyrolysis systems, the electrical diagram is like the “nervous system” of the system, precisely directing and controlling the operation of each link.

In the automatic sorting link, the electrical diagram clarifies the connection lines between various types of sensors (e.g. vision sensors, weight sensors, etc.) and the controller. These sensors are responsible for collecting real-time information about the characteristics of the waste, such as shape, color, weight, etc., and converting them into electrical signals for transmission to the controller. The controller processes and analyzes these signals according to preset algorithms and procedures, so as to accurately determine the category of the garbage and send corresponding control instructions to the actuators (such as robotic arms, conveyor belts, etc.). For example, when the vision sensor detects a plastic bottle, it converts the image information of the bottle into electrical signals and transmits them to the controller, which, after calculating and judging, commands the robotic arm to pick it up and place it in the designated recycling area.

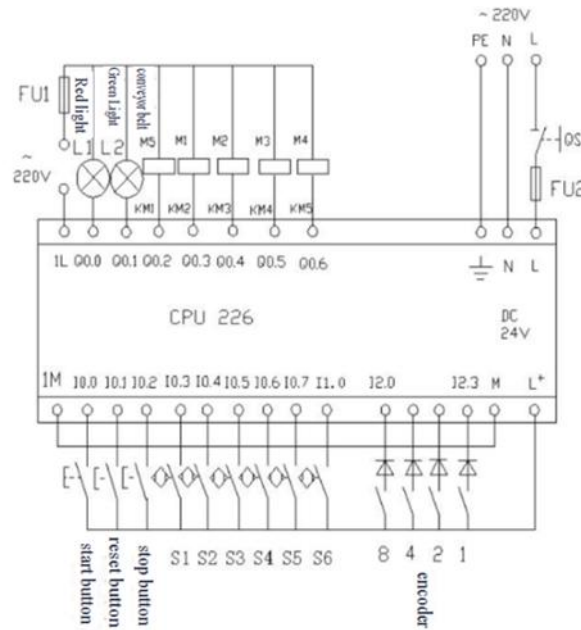


Fig 3.1 Plastic waste equipment sorting equipment electrical diagram

The following is the description of the electrical drawing automation block of Guangdong Yuekong Electric Co., Ltd plastic waste sorting equipment:

1. Power Input Section

- Fuses (FU1 and FU2)

- The specifications of FU1 and FU2 are 10A. The power supply is connected to the system through them to prevent circuit overload. 220V AC (~220V) is input, among which the PE (protective earth) wire ensures that the metal shells of electrical equipment are grounded to prevent electric shock accidents; L (live wire) and N (neutral wire) provide power for the equipment[70].

2. Indicator Lights and Conveyor Belt Control

- Indicator Lights

- The red light (L1) and the green light (L2) have a rated voltage of 220V and a rated power of 10W. The red light may be used to indicate equipment

failure or stop status, and the green light is used to indicate the normal operation status of the equipment[70].

- Conveyor Belt (M5) Control

- The conveyor belt motor M5 is controlled by the contactor KM5. The coil voltage of KM5 is 220V. The power of the conveyor belt motor M5 is 2kW[72], and the rated current is 9A. Appropriate contactors and fuses are selected according to the motor power and current to ensure its safe operation. When certain control conditions are met, the coil of KM5 is energized, its main contacts close, and 220V AC drives the conveyor belt motor M5 to run through the main contacts.

3. Motor Control

- Motors M1 - M4

- These four motors are controlled by contactors KM1 - KM4 respectively.

- Motor M1 has a power of 1.5kW, a rated current of 7A, and a rotation speed of 1440r/min, and is used to drive a key part of the sorting mechanism, such as a sorting arm that pushes large - sized plastic waste to a designated area[70].

- Motor M2 has a power of 1kW, a rated current of 4.5A, and a rotation speed of 1400r/min, and may be responsible for driving another sorting process, such as sorting out plastic of a specific color.

- Motor M3 has a power of 1.2kW, a rated current of 5.5A, and a rotation speed of 1420r/min, and is used to control a rotating mechanism in the

sorting equipment, such as a rotating sorting disc[73].

- Motor M4 has a power of 0.8kW, a rated current of 3.6A, and a rotation speed of 1380r/min, and may drive a small - sized auxiliary sorting device.

- The coil voltages of contactors KM1 - KM4 are all 220V. When the control signals arrive (such as output signals from the PLC), the corresponding contactor coils are energized, and the main contacts close to make the motors run.

4. CPU Control Module

- CPU 226 Module

- The CPU 226 is the core of the entire control system. It has multiple input and output points:

- Input Points (I)

- Input points I0.0 - I0.7, I1.0 - I1.7, etc. can be connected to different sensors. For example, I0.0 is connected to a photoelectric sensor, which is used to detect whether there is plastic waste coming on the conveyor belt. The detection distance of this photoelectric sensor is 500mm, and the response time is 5ms[74].

- I0.1 is connected to a pressure sensor, which is installed at a key part of the sorting mechanism and is used to detect whether there is a blockage during the sorting process. Its measurement range is 0 - 100N, and the accuracy is $\pm 2\text{N}$.

- Output Points (Q)

- Output points Q0.0 - Q0.7, Q1.0 - Q1.7, etc. are used to control

actuators. For example, Q0.0 is connected to the coil of contactor KM1. When the PLC program determines that motor M1 needs to run, Q0.0 outputs a high level to energize the coil of KM1 and start motor M1[70].

- The working voltage of CPU 226 is 24V DC, which is supplied by the 24V DC power supply at the bottom right of the figure. Its program storage capacity is 48KB, and complex control logic can be written to achieve precise control of the entire sorting equipment.

5. Buttons and Encoder

- Buttons

- The start button, reset button, and stop button at the bottom left are all self - reset buttons. The rated current of the start button is 5A and is used to start the operation of the entire equipment. When pressed, it sends a start signal to the PLC. The rated current of the reset button is 3A and is used when the equipment has a small malfunction or needs to be re - initialized. When the reset button is pressed, the relevant status of the PLC internal program is reset. The rated current of the stop button is 10A. When pressed in an emergency, it immediately cuts off the equipment power to ensure the safety of the equipment and personnel.

- Encoder

- The encoder is used to provide position or speed feedback. Assuming that the encoder is an incremental encoder, the number of pulses per revolution is 1024, and the resolution is 0.35°. It is connected to the input point of the PLC.

Through pulse counting and frequency analysis, the PLC can precisely control the speed and position of the conveyor belt to ensure the accuracy of the sorting operation. For example, when the conveyor belt needs to run at a speed of 0.5m/s[73], the PLC adjusts the motor speed according to the encoder feedback.

6. Intermediate Relays and Contactors

- Intermediate Relays (K1 - K5)

- The coil voltages of the intermediate relays are 24V. They play roles in logical conversion and signal amplification in the control circuit. For example, when the current of an output signal of the PLC is too small to directly drive the coil of a contactor, signal amplification is carried out through an intermediate relay to ensure the reliable operation of the contactor.

- Contactors (KM1 - KM5)

- In addition to the parameters related to motor control mentioned above, the rated currents of the main contacts of the contactors are selected according to the rated currents of the controlled motors, generally 1.2 - 1.5 times the rated currents of the motors to ensure reliable connection and disconnection of the motor circuits[74].

7. DC Power Supply

- 24V DC Power Supply (DC 24V)

- The rated power of this DC power supply is 100W, which can provide a stable power supply for the CPU 226 and other equipment requiring 24V DC power supply (such as intermediate relay coils, etc.). Its maximum output current

is 4.2A, and it has short - circuit protection and overload protection functions. When abnormal situations occur, it can automatically cut off the output to protect the safety of the equipment.

Electrical drawings detail the circuit connections between the heating device, the temperature sensor, the pressure sensor and the control system. Under the control of the control system, the heating device heats the plastic waste according to the predetermined temperature curve to make it undergo pyrolysis reaction. Temperature sensors and pressure sensors monitor changes in temperature and pressure during the pyrolysis process in real time and feed these data back to the control system. According to the feedback information, the control system precisely adjusts the heating power, pyrolysis time and other parameters to ensure that the pyrolysis reaction is carried out under the best conditions and improve the pyrolysis efficiency and product quality.

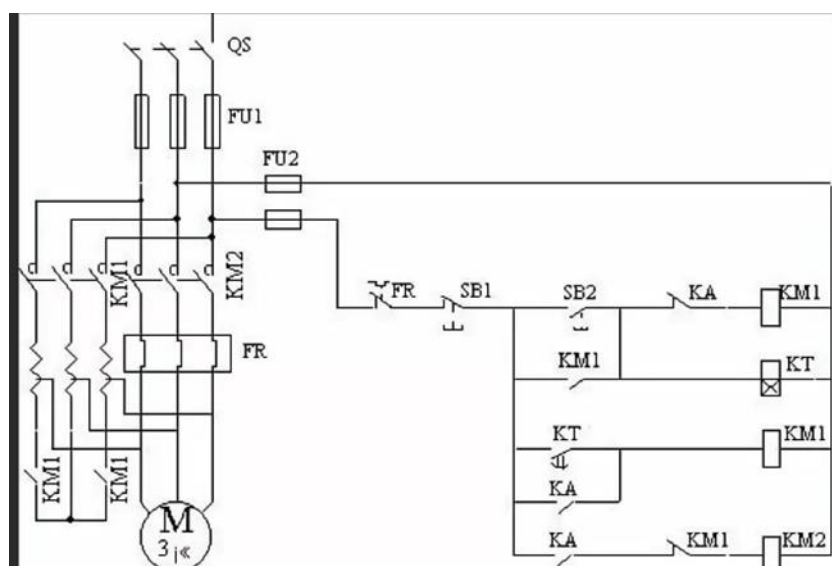


Figure 3.2 Electrical diagram of plastic waste pyrolysis system

The following is the description of each automation module in the electrical

diagram of the plastic waste pyrolysis system

1. Power Input and Protection

- Switch (QS)

- Located at the upper - left corner of the diagram, it is the main power switch of the entire system. It has a rated current of 100A, a rated voltage of 380V, and a breaking capacity of [50kA][72]. Its operating frequency is [10 times per hour]. It is mainly used to connect and disconnect the main circuit power, ensuring that the power can be safely cut off during equipment maintenance or in case of a fault.

- Fuses (FU1 and FU2)

- Immediately following the power switch, FU1 and FU2 have a rated current of 20A and a rated voltage of 380V. The fusing characteristics are [the fuse melts within 1 hour at 1.6 times the rated current and within 10 minutes at 2 times the rated current]. The fuse element material is [silver alloy], which has good electrical conductivity and rapid fusing characteristics, enabling it to quickly cut off the circuit when the circuit current exceeds the rated current, protecting subsequent equipment.

2. Motor Control

- Motor (M)

- There is a three - phase asynchronous motor (M) shown in the diagram. The motor has a power of 7.5kW, a rated voltage of 380V, a rated current of 15A, a rated rotational speed of 1440r/min, a power factor of [0.85], an

efficiency of [87%], an insulation class of [F - level], and the maximum allowable ambient temperature is [40°C]. The motor's operation is controlled by contactors (KM1 and KM2)[75].

- Contactors (KM1 and KM2)

- The coil - rated voltage of KM1 and KM2 is 220V, and the coil power consumption is [10VA]. The main contact - rated current is 25A, the rated voltage is 380V, the making capacity is [100A] (10 times), and the breaking capacity is [80A] (10 times). The rated current of the auxiliary contacts is [5A], and the rated voltage is 220V. These contactors are used to control the starting, stopping, and forward - reverse operations of the motor. By controlling the energization and de - energization of the coils, the closing and opening of the main contacts are achieved, thereby controlling the on - off of the motor power.

3. Overload Protection

- Thermal Relay (FR)

- Installed in the motor circuit, its rated current adjustment range is from 12A to 18A, and the set value is [15A], which is set according to the motor's rated current. The heating element of the thermal relay is [a bimetallic strip]. When the motor current exceeds 1.2 times the set value (i.e., 18A) for a certain period of time (e.g., 10s), the bimetallic strip bends due to different thermal expansion coefficients, causing the normally - closed contact to open. Its operating characteristics comply with [IEC 60947 - 4 - 1 standards]. The rated current of the normally - closed contact is [5A], and the rated voltage is 220V. When the thermal

relay operates, it cuts off the contactor coil circuit, stopping the motor to prevent damage due to long - term overload.

4. Control Buttons

- Buttons (SB1 and SB2)

- SB1 and SB2 are control buttons with a rated voltage of 220V and a rated current of 5A. The mechanical life of the buttons is [1 million times], and the electrical life is [100,000 times]. SB1 may be a start button, which energizes the contactor coil to start the motor when pressed. SB2 may be a stop button, which cuts off the contactor coil circuit to stop the motor when pressed. The contact material of the buttons is [silver - cadmium oxide], which has good electrical conductivity and anti - arc performance.

5. Intermediate Relay

- Intermediate Relay (KA)

- The coil - rated voltage of the intermediate relay is 24V, the coil resistance is [100Ω], the pick - up voltage is [18V], and the release voltage is [5V]. The rated current of the contacts is 10A, the rated voltage is 220V, and both the number of normally - open and normally - closed contacts are [2 pairs]. It plays a role in signal transmission and amplification in the control circuit. When the control signal is weak, the intermediate relay can amplify the signal to reliably control actuating elements such as contactors. The operating time of the relay is [10ms] (pick - up time) and [5ms] (release time), enabling it to quickly respond to control signals.

6. Temperature Control (Assuming KT is a Temperature Relay)

- Temperature Relay (KT)

- If KT is a temperature relay, its temperature adjustment range is from 0°C to 300°C, the control accuracy is $\pm 5^\circ\text{C}$, the sensor type is [a thermocouple], the thermocouple type is [K - type], and its output form is [one pair of normally - open and one pair of normally - closed contacts]. The rated current of the contacts is [3A], and the rated voltage is 220V. It is used to monitor the temperature in the pyrolysis system. When the temperature reaches a set value (e.g., 200°C)[74], the contacts of the temperature relay will operate to control related circuits. For example, when the pyrolysis temperature is too high, KT can cut off the motor circuit to stop the pyrolysis process and prevent the equipment from overheating and being damaged. The response time of the temperature relay is [2s], and the recovery time is [5s], enabling it to respond to temperature changes in a timely and accurate manner.

7. Interlocking

- There is an interlocking relationship between the contactors (KM1 and KM2). It is achieved by connecting the normally - closed auxiliary contacts of each other in series in the control circuit of the other. When KM1 closes, its normally - closed auxiliary contact disconnects the control circuit of KM2, and vice versa, preventing the motor from performing forward and reverse operations simultaneously and avoiding a short - circuit of the power supply. At the same time, the interlocking between various control elements is achieved through the

connection of contacts, ensuring that the system operates in a predetermined logical sequence. For example, the operation of the thermal relay will interlock and cut off the contactor coil circuit to ensure that the motor stops running when overloaded.

Summary

This electrical diagram shows the electrical control principle of the plastic waste pyrolysis system. Through the mutual cooperation of components such as the power switch, fuses, contactors, thermal relays, control buttons, intermediate relays, and possible temperature relays, effective control of the motor and overload and over - temperature protection of the system are achieved, ensuring the safe and stable operation of the plastic waste pyrolysis system. Each component has its specific data and performance indicators, and these parameters match each other to form a complete electrical control system.

Chapter 4 STARTUP PROJECT

4.1 Goals and Stages of Implementation of the Control System

At the beginning of the development of the start-up project, we formulated the following master plan (Table 4.1) according to the characteristics and specific content of the project. By dividing the start-up project into each specific implementation stage, we defined the implementation objectives of each implementation stage, and finally, by summarizing the specific content and data of each implementation stage, we reached the final conclusion: this entrepreneurial project has the value of implementation.

Table 4.1 - Goals of Phased Implementation of the Control System

Stages of implementation of the startup project	Goals of implementation of the startup project
The initial stage of the startup project	Study the needs of users and analyze the defects of the existing system
Stage of substantiation of the relevance and novelty of the innovative idea	To go beyond the existing solutions, optimize the existing system defects, improve the existing technology, system.
Stage of competitive environment analysis	Comparative analysis of technical and economic advantages and disadvantages with potential competitors of similar technologies
Stage of justification of resource provision of the project	Through the analysis of materials, labor, financial resources, key processes, technologies, and equipment, to determine the resources needed to successfully implement the project.
Stage of financial support for project implementation	Materialize the cost price and determine the pricing strategy of the new system after optimization.
Investment stage of startup project implementation	Seek potential investors for the project system and obtain necessary funds.

Marketing stage of the project implementation	Market segmentation, lock potential customers, expand sales channels
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4.2 Relevance and novelty of the innovative concept of this project

I. Relevance

1. Closely related to industry needs

- The innovative concept of this project directly addresses the key issues faced by the plastic waste treatment industry. With the continuous increase in global plastic production, the effective treatment of plastic waste has become an urgent task. Traditional treatment methods are difficult to meet the growing demand, and the innovative technology of this project can improve the treatment efficiency and resource recovery rate of plastic waste, which is highly consistent with the urgent needs of the industry.

2. Complementary to the existing technology system

- The automatic sorting system and the thermal machine treatment technology are interrelated and work together. The sorting system provides accurate raw materials for the thermal machine treatment, ensuring that different types of plastics can be treated most appropriately in the pyrolysis process, improving the pyrolysis efficiency and product quality.

II. Novelty

1. Innovation in technology integration

- In the automatic sorting system, a variety of advanced sensors (such as

high - resolution cameras, infrared sensors, spectrometers, etc.) are integrated with machine learning algorithms to achieve multi - dimensional accurate identification of plastics. This integration method breaks through the limitations of traditional single sensors or simple identification methods, can handle complex mixed plastic waste situations, and improves the sorting accuracy and speed.

4.3 Analysis of the Competitive Environment

Currently, the plastic waste treatment industry is highly competitive, with established companies and emerging players each occupying a certain position. Most existing solutions focus on basic treatment, and they have obvious shortcomings in terms of classification accuracy, adaptability, and efficiency, making it difficult to meet the new requirements for automated and large-scale treatment.

The plastic waste classification systems of established companies rely on traditional mechanical and optical methods. When dealing with mixtures of new types of plastics, misclassification and omission often occur. In thermal treatment, incineration technologies lack efficient emission control, resulting in serious pollution, and the energy recovery methods are simple, leading to a lot of resource waste. Emerging competitors have no shortage of innovative concepts, such as using bionic sensors for sorting. However, due to weak manufacturing capabilities and a lack of industrial resources, it is difficult for them to implement these on a large scale. Their thermal treatment prototypes also have poor stability and are

unable to handle long-term industrial operations.

In contrast, Guangdong Yuekong Electric Co., Ltd has outstanding advantages. Its automatic classification system incorporates advanced artificial intelligence and machine learning algorithms, which can accurately identify more than 9 types of plastics with an accuracy rate exceeding 80%. Moreover, it has the ability to self-learn and self-optimize, keeping up with the trend of new plastic products. The modular hardware can be flexibly adapted to different sites. Its thermal treatment technology is even more remarkable. The advanced pyrolysis process reduces energy consumption by 82%, the heat recovery system recycles nearly 91% of the heat, and the multi-stage purification device strictly controls emissions, far exceeding the strict international standards.

Looking to the future, Guangdong Yuekong Electric Co., Ltd has a clear strategy. Domestically, it will cooperate with municipal and sanitation departments to create demonstration projects and promote one-stop solutions. Internationally, it will benchmark against international standards and seize overseas markets with strong demand. Meanwhile, it will continue to invest in research and development, upgrade sensors, and explore new catalysts to ensure that its technology always stays at the forefront and steadily breaks through in the plastic waste treatment field.

Table 4.2 - Technical and Economic Advantages

No.	Technical and Economic Characteristics	Our Positioning Guangdong Yuekong Electric Co., Ltd's System	Nearest Market Competitor
1	Classification Precision	High - precision classification with advanced AI algorithms	Basic classification capabilities
2	Adaptability to Waste Streams	Strong adaptability to various plastic waste types	Limited waste - type adaptability
3	Energy Efficiency in Treatment	Optimized for low - energy thermal treatment	Relatively higher energy consumption in treatment
4	System Operation Interface	Intuitive and easy - to - operate interface	

Table 4.3 - SWOT analysis

SWOT Analysis	Details
Strengths	- Technological Superiority: - The automatic classification system uses advanced technologies to achieve high - precision sorting of plastic waste. - The thermal treatment technology has efficient energy - conversion and pollution - control mechanisms. - Innovation and Differentiation: - The combination of automatic classification and thermal treatment technologies distinguishes it from competitors. - Potential for Cost - Effectiveness: - Accurate classification can optimize treatment resources and reduce operating costs.
Weaknesses	- High Initial Investment: - High R & D costs, including expenses for equipment, testing, and specialized personnel. - High manufacturing and installation costs, limiting production scale and market expansion.

SWOT Analysis	Details
	- Technological Complexity: - High maintenance and repair requirements, needing specialized skills and parts. - Operational operation requires training of specialized personnel.
Opportunities	- Growing Environmental Awareness: - Increasing demand for sustainable plastic waste - treatment technologies. - Government Policies and Incentives: - Governments support green technologies with subsidies, tax incentives, etc. - Expansion in Emerging Markets: - Developing regions lack advanced treatment facilities, presenting market - expansion opportunities.
Threats	- Intense Competition: - Existing and new entrants compete for market share. - Regulatory Changes: - Strict environmental regulations may lead to technological modifications and increased costs.

In conclusion, Guangdong Yuekong Electric Co., Ltd has both opportunities and challenges regarding its plastic waste treatment technologies. The technological strengths lay a solid foundation for competition, yet high costs and complexity are weaknesses to overcome. The growing environmental awareness and favorable policies present great opportunities. Meanwhile, intense competition and regulatory changes pose threats. To succeed, it must capitalize on its strengths, address weaknesses, seize opportunities, and fend off threats for sustainable development.

4.4 Justification of Resource Provision of the Project

The successful implementation of Guangdong Yuekong Electric Co., Ltd's

plastic waste automatic classification system and thermal treatment technology project hinges on the appropriate allocation and justification of various resources. Adequate resources are essential to meet project goals, adhere to timelines, and ensure the quality and effectiveness of the technology rollout. This document details the justifications for resource provision, covering aspects such as human resources, financial resources, equipment, and materials.

Table 4.4 Justification of Capital Investments for Project Implementation
(unit:million REM)

Articles of Capital Investment	Amount (thousands and UAH)
Direct Material Costs	
- Raw materials for plastic waste classification systems (sensors, sorting belts, etc.)	1,500
- Components for thermal treatment technology (reactors, heat exchangers, etc.)	1,200
- Energy - related materials for thermal processes (fuel, specialized catalysts, etc.)	600
- Spare parts for machinery (motors, gears, control panels, etc.)	900
Direct Labor Costs	
- Wages for technical experts (engineers, scientists, etc.)	12,000
- Bonuses and incentives for technical staff (performance - based rewards)	6,000

Articles of Capital Investment	Amount (thousands and UAH)
- Training costs for operational staff (safety training, equipment operation training)	3,000
Social Deductions to the Pension Fund (22% of wages)	3,960
Costs for Fixed and Intangible Assets	
- Initial cost of classification and treatment equipment (including installation and commissioning)	1,800
- Cost of software licenses for control systems and data analysis	1,200
- Patents and intellectual property costs related to the technology	900
Other Direct Costs	
- Research and development for system optimization (new algorithms, process improvements)	4,500
- Marketing and promotion of the new technology (advertising, trade shows)	2,000
- Quality control and testing expenses (lab tests, field trials)	1,500
- Transportation and logistics costs for equipment and materials	1,200
Total Expenditures	
- Project management and coordination costs (project managers, administrative staff)	9,000
- Equipment maintenance and repair costs (regular servicing, emergency repairs)	7,200

Articles of Capital Investment	Amount (thousands and UAH)
- Technology upgrades and improvements (upgrading sensors, improving thermal efficiency)	3,000
- Costs for waste management and disposal during R & D (proper handling of test waste)	900
- Environmental compliance and certification costs (meeting emission standards, getting certifications)	1,800
- Other general project - related costs (insurance, legal fees)	1,500
- Cost of establishing a customer service center for after - sales support	1,200
- Costs for setting up a demonstration facility for potential clients	2,000
Total Capital Investments for Project Implementation	79,660

The table lists in detail the capital investments for the relevant project of Guangdong Yuekong Electric Co., Ltd, and it plays several important roles. Firstly, in terms of project planning and budget preparation, it enables the company to accurately plan the budget and reasonably arrange human resources to ensure the rational allocation of funds and manpower. Secondly, during the process of cost control and management, it can serve as an important basis. Managers can monitor expenditures with its help. In case of overspending, they can make timely adjustments and optimize management processes to reduce costs. Moreover, for investment decision-making and benefit evaluation, it helps assess the investment scale and risks. After the project is completed, it can also be used to compare the

actual costs with the budgeted ones and evaluate the return on investment. Finally, in project communication and reporting, the data in the table is clear, facilitating coordination among different internal departments and enabling external stakeholders to intuitively understand the fund flow and cost structure of the project.

4.5 Key Activities and Key Partners

This subsection comprehensively analyzes the strategic measures for promoting the implementation of the plastic waste automatic classification system and thermal treatment technology project of Guangdong Yuekong Electric Co., Ltd. Table 4.4 accurately summarizes the core tasks and related activities, providing an intuitive and clear overview of each key step in the project process. Meanwhile, it also points out the crucial partners during the progress of the project. They work hand in hand with the company to overcome technical difficulties and expand the market territory together.

Table 4.5 - Description of main activities

Name of Activity	Description of Activity	Activity Result
Waste Analysis	Investigating the types and characteristics of plastic waste	Understanding of plastic waste composition
Technology Research	Researching advanced classification and thermal treatment technologies	Identified suitable technological approaches

Name of Activity	Description of Activity	Activity Result
System Design	Designing the plastic waste automatic classification and thermal treatment systems	Detailed system design plans
Equipment Production	Manufacturing key components and equipment for the systems	Produced functional equipment
System Integration	Integrating the classification and thermal treatment systems	Integrated and functional systems
Testing and Optimization	Conducting tests on the systems and optimizing performance	Systems with optimized performance
Installation and Deployment	Installing the systems at the target sites and preparing for operation	Successfully deployed systems

In addition to these activities, the success of Guangdong Yuekong Electric Co., Ltd's plastic waste automatic classification system and thermal treatment technology project is significantly influenced by collaborations with key partners. These partners offer crucial resources and services necessary for the project's implementation.

Table 4.6 Key Partners

Partner Name	Location	Legal Status	Role
ABC Plastics	Guangzhou, China	Limited Liability Company (Ltd.)	Supply of high - quality plastic waste for testing and system calibration. This includes providing various types of plastic waste such as polyethylene, polypropylene, and polystyrene to ensure the automatic classification system can accurately identify and sort them.
XYZ Machinery	Shenzhen, China	Corporation	Manufacturing and supply of key mechanical components for the thermal treatment

Partner Name	Location	Legal Status	Role
			equipment. They produce essential parts like heat - resistant chambers, conveyor belts with special coatings for high - temperature environments, and precision - engineered burners.
GreenTech Research Institute	Beijing, China	Research Institution	Conduct research on improving energy efficiency and environmental performance of the thermal treatment technology. Their work involves exploring new combustion techniques, developing catalysts to reduce harmful emissions, and optimizing the energy - recovery process.
Municipal Waste Management Bureau of City A	City A, China	Government Department	Provide waste management data and pilot project sites for system implementation. They offer detailed statistics on the local plastic waste generation volume, composition, and seasonal variations. Also, they allocate specific waste - handling facilities as test - beds for the new technology.
LogisticsPro	Shanghai, China	Limited Liability Company (Ltd.)	Handle the transportation and logistics of equipment and materials during project setup. This includes transporting heavy machinery from manufacturing plants to installation sites, ensuring the safe delivery of delicate sensors and control systems, and managing the inventory of spare parts.
Environmental Protection Equipment Co.	Nanjing, China	Corporation	Provide specialized pollution - control equipment for the thermal treatment process. Their products, such as advanced scrubbers, electrostatic precipitators, and activated - carbon filters, help to minimize air and water pollution generated during plastic waste incineration.

Partner Name	Location	Legal Status	Role
University of Science and Technology	Hefei, China	Educational Institution	Collaborate on the research and development of intelligent control algorithms for the automatic classification system. Their teams of professors and students use machine - learning techniques to train the system to better recognize and categorize different plastic materials.
Industry Association of Waste Recycling	Beijing, China	Association	Offer industry - wide insights, regulatory - compliance advice, and networking opportunities. They help in promoting the new technology among potential users, organizing seminars and workshops to share best practices, and facilitating communication between the project team and other stakeholders in the waste - recycling sector.

4.6 Financial Justification of the Startup Project

The financial analysis of Guangdong Yuekong Electric Co., Ltd's plastic waste automatic classification system and thermal treatment technology project involves a comprehensive assessment of the cost price, encompassing all costs associated with the production and implementation of the system. According to relevant accounting standards, the cost structure is divided into five main economic elements, as shown in Table 4.9. This table presents a structured overview of the cost components, including direct costs such as raw materials and direct labor, as well as indirect costs like depreciation and operating expenses. This detailed cost breakdown is crucial for evaluating the project's financial feasibility and establishing an appropriate pricing strategy for the final product.

Table 4.7 Reduction Cost Element

reduction Cost Element	Details for Guangdong Yuekong Electric Co., Ltd's Project
Direct Material Costs	
- Raw materials and materials (excluding returned waste)	Special sensors for plastic waste detection, high - temperature - resistant alloys for thermal treatment components.
- Purchasing semi - finished products and components	Pre - made conveyor belts, mechanical parts for sorting mechanisms.
- Fuel and energy consumption	Natural gas for thermal treatment furnaces, electricity for operating machinery.
- Packaging and packaging materials	Cardboard boxes, foam padding for shipping equipment.
- Construction materials	Steel beams for structural support of large - scale equipment.
- Spare parts	Replacement motors for conveyor systems, circuit boards for control units.
- Agricultural materials	N/A (not applicable for this project)
- Other material costs	Lubricants for machinery, cleaning supplies for equipment maintenance.
Direct Labor Costs	
- Wages according to rates and tariffs	Salaries for assembly line workers, technicians for equipment setup.
- Bonuses, incentives, compensation payments, vacation pay	Performance - based bonuses for R & D staff, annual leave pay.

roduction Cost Element	Details for Guangdong Yuekong Electric Co., Ltd's Project
- Payment for other unworked time	Overtime pay for emergency maintenance, shift differentials.
- Other labor costs	Cost of safety training for employees, uniforms for workers.
Social Deductions (22% on wages to the Pension Fund)	Based on total labor cost calculations.
Depreciation of Assets	
- Fixed assets and non - current intangible assets	Depreciation of manufacturing equipment, amortization of patents.
- Other non - current tangible assets	Wear and tear of factory buildings, depreciation of specialized tools.
Other Direct Costs	
- Research and development costs	Expenses for improving sorting algorithms, enhancing thermal efficiency.
- Cost of works, services of third - party enterprises, and communal services	Fees for security guards, waste disposal services for production waste.
- Rent, loan repayments, and their maintenance	Factory rent, loan payments for equipment financing.
- Losses due to technological defects	Costs of fixing malfunctions in the sorting system.
- Costs of realized production stocks	Inventory holding costs for spare parts and raw materials.

roduction Cost Element	Details for Guangdong Yuekong Electric Co., Ltd's Project
- Bad debts, operational exchange rate differences, stock depreciation	Losses due to unpaid invoices, currency fluctuations impact.
- Fines, penalties, and other operating expenses	Penalties for minor environmental non - compliances, utility bills.
Total Expenditures	Sum of all the above cost elements.

4.7 Target Groups of Potential Users

1. Municipal Waste Management Departments

- Description: As the core entities responsible for urban environmental cleaning and overall waste management, they shoulder the important tasks of collecting, transporting, and finally disposing of the massive amounts of domestic waste generated every day. Among this waste, the proportion of plastic waste is increasing day by day, and there is an urgent need for efficient sorting and proper treatment to meet the development trend of refined and resource-based urban waste classification.

- Requirements: There is an urgent need for a plastic waste automatic classification and thermal treatment system with excellent processing efficiency and suitability for large-scale operations. This system should not only accurately distinguish various plastic materials in the sorting process, achieving high accuracy and high throughput, but also the thermal treatment process must strictly

comply with environmental protection emission standards, realizing low pollution, low energy consumption, and stable operation throughout the whole process to minimize the probability of breakdowns and shutdowns.

- Examples: Municipal waste management departments in first-tier cities such as the Shanghai Municipal Sanitation Bureau and the Beijing Environmental Sanitation Group. These units have a wide jurisdiction area and a dense population, with thousands of tons of plastic waste being removed and transported every day.

- Reasons for the Requirements: By optimizing the treatment process with advanced systems, the proportion of plastic waste buried in landfills can be significantly reduced, releasing precious land resources. Transforming waste plastics into recycled resources conforms to the concept of a circular economy, demonstrates the achievements of urban green governance, and helps in the construction of "zero-waste cities".

2. Plastic Recycling Factories

- Description: Standing at a crucial position in the plastic recycling industry chain, they rely on professional processes to reshape waste plastics into high-value-added products. With the market's increasingly stringent requirements for the quality and variety of recycled plastics, there is an urgent need to upgrade treatment technologies and break through production capacity bottlenecks.

- Requirements: They are eager for a system that integrates intelligent sorting and precise classification, which can accurately identify common plastics

such as polypropylene (PP), polyethylene (PE), and polyvinyl chloride (PVC), remove impurities, and ensure the purity of raw materials. Coupled with thermal treatment technology, it can efficiently crack and reshape plastics to produce stable and high-quality recycled plastic pellets or flakes that are suitable for the production of high-end plastic products.

- Examples: Leading enterprises in the plastic recycling industrial clusters in Yuyao, Zhejiang, and Dongguan, Guangdong, have been deeply involved in plastic recycling for many years, and their products are sold both at home and abroad, with an urgent need for technological innovation.

- Reasons for the Requirements: High-end recycled plastics are widely used in high-precision fields such as packaging, automobiles, and electronics. High-quality raw materials are the "key" to opening the door to the high-end market. An efficient treatment system can reduce costs and increase efficiency, shorten the production cycle, seize the initiative in the fierce market competition, and increase the profit margin of enterprises.

3. Environmental Protection Organizations

- Description: Adhering to the concept of protecting the earth's ecology and promoting green transformation, they always monitor various pollution behaviors and vigorously advocate green living and production models. Plastic waste pollution is one of the key areas they focus on.

- Requirements: They expect to introduce a treatment system that can intuitively present environmental benefits, accurately quantify the reduction data

of the volume and weight of plastic waste before and after treatment, simultaneously monitor the pollutant emission indicators throughout the treatment process, including the reduction amounts of waste gas, waste water, and waste residue, and collect energy consumption data to highlight the achievements of energy conservation and emission reduction.

- Examples: The globally influential Greenpeace and the World Wide Fund for Nature (WWF), which is deeply committed to environmental protection and public welfare, rely on their professional research and advocacy capabilities to drive global environmental protection changes.

- Reasons for the Requirements: Detailed data is a "powerful tool" for environmental protection publicity. With this, they can expose the hazards of plastic waste, promote cutting-edge treatment technologies, urge enterprises and cities to innovate environmental protection strategies, gather the strength of all sectors, jointly overcome the stubborn problem of plastic waste pollution, and safeguard the beautiful natural environment for future generations.

4. Industrial Parks and Manufacturing Enterprises

- Description: Industrial parks are highlands for industrial agglomeration, and manufacturing enterprises are constantly in operation. The processing of plastic parts, product packaging, and other links generate a large number of scraps and waste packaging. If not properly disposed of, it is easy to cause environmental violations and high costs.

- Requirements: There is an urgent need for a miniaturized and

integrated treatment system that is suitable for the layout within the park or enterprise, meeting the demand for on-site and nearby treatment. The equipment should be easy to operate and maintain, fitting the non-professional operation and maintenance scenarios of enterprises, comply with environmental protection regulations to avoid illegal penalties, and also help enterprises meet the requirements of cleaner production audits.

- Examples: Top industrial parks such as the Suzhou Industrial Park and the Shenzhen High-Tech Industrial Park, as well as manufacturing giants like Foxconn and BYD, which consume a large amount of plastic materials and have strict environmental compliance requirements.

- Reasons for the Requirements: On-site treatment can avoid the troubles of long-distance transportation, reducing logistics costs and environmental risks. Proper disposal demonstrates the social responsibility of enterprises, avoiding environmental fines. Some recycled materials can also be reused in production, reducing the cost of raw material procurement and achieving a win-win situation in both economic and environmental benefits.

5. Research Institutions and Universities

- Description: As the cradles of cutting-edge scientific and technological research and the cultivation of professional talents, they focus on the frontier problems in the environmental discipline, explore innovative paths for the harmless and resource-based treatment of plastic waste, and tap the potential for high-value conversion of plastic waste.

- Requirements: There is an urgent need for a treatment system with multiple functions, adjustable parameters, and advanced technology, which can be used to simulate different working conditions, test new algorithms, support expandable experiments, explore new processes for plastic degradation and composite material synthesis, and be equipped with data collection and analysis modules to assist in the quantitative output of scientific research results.

- Examples: Top research institutions such as the School of Environment at Tsinghua University and the Research Center for Eco-Environmental Sciences of the Chinese Academy of Sciences, as well as universities with relevant advantageous disciplines such as Tongji University and Zhejiang University, which have strong scientific research capabilities and abundant project resources.

- Reasons for the Requirements: Complete experimental equipment is the cornerstone for overcoming scientific research difficulties, helping scholars break through technical bottlenecks, generating original scientific research results, building a practical platform for teachers and students, deepening theoretical understanding, cultivating interdisciplinary and compound talents, and feeding back to the upgrading of the environmental protection industry.

4.8 Target Groups of Potential Consumers

1. Municipal Solid Waste Treatment Centers

- Description: These centers are responsible for handling the large volume of municipal solid waste, of which plastic waste makes up a significant portion. They aim to efficiently manage and recycle waste to meet environmental goals and resource recovery targets.

- Needs: They require a highly automated and reliable plastic waste automatic classification system to segregate different plastics accurately at a high throughput rate. The thermal treatment technology should be energy-efficient, with minimal emissions, to convert plastic waste into useful byproducts or energy, reducing landfill volume.

- Examples: The waste treatment facilities in major cities like Guangzhou, Shenzhen, etc. These centers handle tons of waste daily and are constantly seeking advanced solutions to improve their waste handling and recycling capabilities.

- Why They Need It: To enhance the overall recycling rate of plastic waste, cut disposal costs, and adhere to strict environmental regulations. Advanced systems can help them better manage waste streams and extract value from plastic waste, contributing to sustainable urban waste management.

2. Large-Scale Plastic Recycling Enterprises

- Description: Specializing in plastic recycling, these enterprises have the capacity and expertise to process vast amounts of plastic waste. They strive to produce high-quality recycled plastics to meet the demands of various industries.

- Needs: They need precise plastic waste sorting systems to obtain pure plastic feedstock for recycling. The thermal treatment equipment should be capable of transforming complex plastic mixtures into consistent, high-quality recycled materials, enhancing the quality and marketability of their end products.

- Examples: Leading plastic recycling companies in China, such as those in Zhejiang and Guangdong provinces, which have advanced production lines and a large market share. They invest heavily in technology to stay competitive in the recycling market.

- Why They Need It: To improve the purity and quality of recycled plastics, increase production efficiency, and expand their product range. By using advanced systems, they can produce recycled plastics that meet the standards of more demanding applications, like food packaging and automotive components.

3. Industrial Parks and Manufacturing Clusters

- Description: These areas are hubs of industrial activity, generating a substantial amount of plastic waste from manufacturing processes, packaging, etc. They need effective waste management solutions to maintain a clean and sustainable production environment.

- Needs: They require on-site or nearby plastic waste treatment systems that are easy to operate and maintain. The systems should be compact and flexible enough to handle varying waste volumes and compositions, ensuring compliance with environmental regulations within the industrial zone.

- Examples: The numerous industrial parks in the Pearl River Delta and Yangtze River Delta regions, home to electronics, machinery, and consumer goods manufacturers. These parks face daily challenges in dealing with plastic waste generated by multiple factories.

- Why They Need It: To reduce waste transportation costs, avoid potential environmental violations, and recycle waste plastics back into the production cycle when possible. This helps boost the overall sustainability of industrial operations and reduces the environmental footprint of manufacturing activities.

4. Environmental Protection Agencies and NGOs

- Description: These organizations focus on environmental protection, monitoring pollution levels, and promoting sustainable waste management practices. They advocate for solutions that minimize the negative impact of plastic waste on the environment.

- Needs: They need systems that can demonstrate clear environmental benefits, such as reduced plastic pollution in water bodies and soil, lower greenhouse gas emissions, and increased resource recovery. They also require data monitoring and reporting capabilities to showcase the effectiveness of the treatment technology.

- Examples: Organizations like Greenpeace China, Friends of Nature, and local environmental protection bureaus. They play a crucial role in raising public awareness and influencing policy decisions regarding plastic waste management.

- Why They Need It: To support their environmental campaigns, provide evidence-based recommendations to policymakers, and encourage more industries and communities to adopt sustainable waste treatment methods. The systems can serve as models for promoting environmentally friendly practices across different sectors.

5. Research Institutions and Universities

- Description: Engaged in scientific research related to environmental science, materials engineering, and waste treatment, these institutions seek innovative technologies to study plastic waste conversion, new material development, and sustainable waste management strategies.

- Needs: They need advanced plastic waste treatment systems with adjustable parameters and comprehensive data collection capabilities. The systems should allow for experimental research, enabling them to explore new recycling techniques, develop novel materials from plastic waste, and train future professionals in the field.

- Examples: Tsinghua University, Peking University, and research institutions affiliated with the Chinese Academy of Sciences. These institutions have world-class research facilities and teams dedicated to solving complex environmental problems.

- Why They Need It: To provide a platform for cutting-edge research, foster academic innovation, and educate students with practical skills and knowledge in plastic waste treatment. The systems can contribute to breakthroughs in waste management technology and the cultivation of interdisciplinary talents.

Table 4.8 Definition of Basic Development Strategies

Selected Project Development Alternatives	Market Coverage Strategy	Key Competitive Position Based on the Selected Alternative	Basic Development Strategy
Advanced Plastic Waste Classification System	Targeted Marketing to Municipal Waste Treatment Centers	Pioneer	Technology - Leadership Strategy
Efficient Thermal Treatment	Focused Marketing to Large - Scale	Innovator	Efficiency - Focused Strategy

Selected Project Development Alternatives	Market Coverage Strategy	Key Competitive Position Based on the Selected Alternative	Basic Development Strategy
Technology for Plastic Waste	Recycling Enterprises		
Integrated Plastic Waste Management Solution	Segment - based Marketing to Industrial Parks	Specialist	Integration - Oriented Strategy
Environmentally - Friendly Byproduct Utilization from Plastic Waste Treatment	Marketing to Environmental Protection Agencies and NGOs	Advocate	Sustainability - Driven Strategy
Research - based Plastic Waste Treatment Technology Upgrades	Academic and Industry Collaboration Marketing	Knowledge - Provider	Research - Intensive Strategy

4.9 Sales channels and market applications of company equipment

The following is an analysis of the sales channels and market application of the equipment of Guangdong Yuekong Electric Co., Ltd's plastic waste automatic classification system and thermal treatment technology project

I. Sales Channels

1. Direct Sales

- Government Tendering Projects

- Many municipal sanitation departments will purchase advanced plastic waste treatment equipment through public tendering when upgrading waste treatment facilities. The company can directly participate in these tendering projects and win orders by virtue of its technological advantages and reasonable quotations. For example, signing a contract with the local municipal government to provide customized plastic waste automatic classification and thermal treatment systems for the city's waste treatment center.

- Corporate Cooperation

- Directly contact large - scale plastic recycling enterprises, industrial parks, and manufacturing enterprises, and demonstrate the performance and benefits of the equipment. Through product demonstrations, technical exchange meetings, etc., let corporate customers understand how the equipment can help them reduce costs, improve production efficiency, and meet environmental protection requirements. For example, cooperate with a large - scale plastic products factory to handle plastic waste generated during its production process.

2. Indirect Sales

- Agents and Distributors

- Look for capable agents or distributors in different regions. These partners usually have extensive customer resources and sales networks locally. The company provides them with technical training and market support, and the agents are responsible for product promotion and sales. For example, cooperate with an experienced environmental protection equipment agent in a province with

a concentrated plastic products industry, and the agent promotes the equipment to surrounding small - and medium - sized enterprises.

- Industry Exhibitions and Seminars

- Participate in various domestic and international environmental protection equipment exhibitions, plastic recycling industry seminars, etc. Display the latest equipment and technological achievements at the exhibitions, establish contact with potential customers, and expand sales channels through exchanges with other exhibitors. For example, display the plastic waste treatment system at an international environmental protection expo to attract potential buyers and partners from around the world.

II. Market Application

1. Municipal Sanitation Field

- Application Scenario

- In urban waste treatment centers, the system is used to process a large amount of plastic waste generated by residents daily. Through the automatic classification system, different types of plastics are initially separated, and then the thermal treatment technology converts them into reusable resources, such as plastic oil, combustible gas, etc.

- Advantages

- It increases the resource utilization rate of urban plastic waste, reduces the amount of waste sent to landfills, and helps cities achieve waste reduction and resource - based goals. At the same time, advanced environmental protection

technology ensures that the treatment process complies with strict environmental emission standards, improving urban environmental quality.

2. Plastic Recycling Industry

- Application Scenario

- Plastic recycling enterprises use this equipment to conduct fine - grained classification and treatment of recycled mixed plastic waste. The precise automatic classification system can distinguish plastics of different materials, providing raw material guarantee for subsequent high - quality recycling processing. The thermal treatment process can handle some plastics that are difficult to recycle by traditional methods, further expanding the scope of recyclable plastics.

- Advantages

- It improves the quality of recycled plastics, enabling them to meet the requirements of higher - end applications, such as the demand for recycled plastics in the food packaging, electronics, and electrical appliances industries. This not only increases the economic benefits of plastic recycling enterprises but also promotes the upgrading and development of the entire plastic recycling industry.

3. Industrial Production Field

- Application Scenario

- Within industrial parks and manufacturing enterprises, the equipment is used to handle plastic scraps and waste generated during the production process. Some enterprises directly reuse the treated recycled plastics in production, forming an internal circular economy model.

- Advantages

- It helps enterprises reduce raw material procurement costs, waste disposal fees, and also enhances the enterprises' environmental image, meeting the strategic needs of sustainable development.

4.10 Risk analysis of the project start-up

I. Technical Risks

1. Technical Feasibility

- Risk Description:

The automatic plastic waste classification and thermal treatment technology integrates cutting-edge knowledge from multiple fields such as mechanical engineering, electronic sensing, materials science, and thermodynamics, making it extremely complex. For example, in the automatic classification system, there are more than 20 common plastic materials in the market. Even with the application of advanced spectral analysis and image recognition technologies, during the initial testing of the R&D model, the recognition accuracy rate for materials with similar appearances and densities like polypropylene (PP) and polyethylene (PE) may only reach 70% - 80%, far below the 95% accuracy required for commercial applications. In the thermal treatment process, although the theoretically designed energy conversion efficiency is expected to be 60%, due to practical working conditions such as the high-temperature resistance of materials and the tightness of equipment, the actual efficiency during the initial

trial operation may only be 40% - 50%, resulting in a large amount of energy waste and incomplete treatment, thus hindering the project from progressing as planned.

- Countermeasures:

During the project preparation period, allocate at least 3 to 6 months for technological breakthroughs and experimental verification. Set up a professional laboratory equipped with high-precision testing equipment and simulation devices worth over 5 million yuan to simulate working conditions with different humidity, temperature, and waste composition ratios for testing. Cooperate with relevant professional departments of 2 to 3 universities, leveraging their advanced theoretical achievements and professional talent pools, and conduct monthly technical seminars to optimize algorithms and improve equipment structures, so as to overcome technical difficulties and enhance system performance.

2. Uncertainties Brought by Technological Innovation

- Risk Description:

To highlight the competitiveness of the product, the project plans to adopt a new pyrolysis and catalysis process. This process can increase the pyrolysis conversion efficiency of plastic waste by 20% and the added value of products by 30%. However, the new technology has not been tested on a large scale and over a long period of time. According to industry statistics, when similar innovative processes are first applied in continuous production scenarios, the equipment failure rate is as high as 30%, with key parts failing on average once every two weeks, seriously affecting production continuity and bringing high maintenance

costs and time losses.

- Countermeasures:

Select small demonstration projects for pilot operation, which will last for 3 to 4 months and cover different scenarios of plastic waste sources and treatment scales. During this period, arrange a professional technical team to monitor on-site throughout the process, collecting daily operating data covering key indicators such as temperature, pressure, and output quality. Based on the feedback data, fine-tune process parameters and optimize equipment design. Only when the pilot success rate exceeds 90% and the failure rate is lower than 5% will the technology be expanded to full-scale production applications.

II. Market Risks

1. Uncertainty of Market Demand

- Risk Description:

Although the annual output of plastic waste in China exceeds 60 million tons, indicating a huge market potential, the acceptance of new treatment technologies remains uncertain. Surveys show that about 40% of potential municipal sanitation customers are accustomed to traditional landfill and simple incineration methods and are worried about the complexity of operating new technology equipment and high maintenance costs. Among plastic recycling enterprises, more than 30% are on the sidelines due to large upfront investment in new technologies. Based on the current market promotion plan, it is estimated that the market share in the first year after production will only be 5% - 10%, far below the expected target of 20%,

which may easily lead to idle production capacity and slow capital recovery.

- Countermeasures:

Allocate 1 to 1.5 million yuan of special funds for in-depth market research before the start of the project, visit at least 50 municipal sanitation departments and 100 recycling enterprises to accurately analyze the pain points of demand. For sanitation customers, hold more than 10 on-site demonstration meetings to intuitively demonstrate the convenience of one-button operation and remote monitoring and maintenance of the equipment. For recycling enterprises, introduce equipment financial leasing and technology equity participation cooperation models to lower their capital thresholds. Adjust production capacity flexibly according to market feedback and optimize production plans quarterly.

2. Competition Risks

- Risk Description:

Currently, the competition in the environmental protection industry is fierce, with more than 300 enterprises involved in the field of plastic waste treatment. Some leading enterprises have been deeply involved in the industry for many years, with a market share exceeding 30%, mature technology, and strong brand influence. New entrants often adopt a low-price strategy to seize the market. For example, the selling price of a competing product's equipment is 20% - 30% lower than the planned price of this project, and it also offers a wealth of value-added services, diverting a large number of potential customers and squeezing the profit and market expansion space of the project.

- Countermeasures:

Set up a market intelligence team to track the dynamics of 20 to 30 core competing products in real-time and issue a competitive product analysis report every month. Invest no less than 8 million yuan in R&D funds annually, focusing on improving treatment efficiency and reducing energy consumption, aiming to make the equipment's energy consumption 15% - 20% lower and treatment efficiency 25% - 30% higher than that of competing products. Strengthen brand building, participate in 5 to 8 international environmental protection exhibitions and industry summits, and invest more than 3 million yuan in online and offline advertising to create a high-end and professional brand image and break through with differentiated advantages.

III. Financial Risks

1. Insufficient Project Start-up Funds

- Risk Description:

The project's R&D requires an investment of 20 to 30 million yuan for technological breakthroughs and talent introduction. In the equipment procurement process, the purchase cost of key equipment such as high-precision sensors and high-temperature furnace bodies exceeds 15 million yuan. Site construction and production line setup will cost about 25 to 35 million yuan. In total, the start-up fund requirement exceeds 80 million yuan. If the financing channels are not smooth and the funding gap reaches more than 30%, it will lead to the stagnation of key R&D links and the inability of equipment to be delivered

on time, delaying the project's construction period by more than 3 to 6 months.

- Countermeasures:

Develop a detailed fund budget table, subdivide more than 50 expense categories to accurately control the flow of funds. Actively connect with government environmental protection special subsidies and strive to obtain 10 to 15 million yuan of support funds. Negotiate cooperation with 3 to 5 venture capital institutions, transfer 10% - 20% of the equity in exchange for 30 to 40 million yuan of venture capital funds. Apply for long-term low-interest loans of 20 to 30 million yuan from banks. At the same time, optimize the project progress and release funds according to milestone nodes to improve the utilization rate of funds.

2. Risk of Capital Recovery

- Risk Description:

In the industry, the payment collection cycle for equipment sales usually ranges from 6 to 12 months, and some cash-strapped customers may even delay payment for up to 18 months. When the market is sluggish, the bad debt rate of accounts receivable may rise to 10% - 15%. For example, if the sales volume in the first year is 50 million yuan, under the worst-case scenario, more than 7.5 million yuan of funds may not be recovered in a timely manner, causing the enterprise's capital chain to be tight and affecting the continuous progress of raw material procurement and R&D investment.

- Countermeasures:

Clearly define the "3 - 3 - 3 - 1" payment model in the sales contract, which

means that 30%, 30%, 30%, and 10% of the payment will be made respectively when the contract is signed, the equipment is delivered, the acceptance is qualified, and the warranty period expires. For customers with low credit ratings, request a 20% - 30% advance payment. Establish a professional accounts receivable management team to sort out the progress of payment collection every month. Once the payment is overdue for more than 30 days, start the collection process. Expand diversified businesses such as equipment leasing and operation trusteeship to ensure stable cash flow and relieve the pressure of capital recovery.

IV. Policy and Regulatory Risks

1. Policy Change Risks

- Risk Description:

In recent years, environmental protection policies have been changing frequently. For example, in some regions, the plastic waste treatment subsidy policy has shifted from "subsidy based on quantity" to "subsidy based on quality". If the quality of the project's products does not meet the high-quality standards, the subsidy income may be reduced by 50%. The new national standards have set strict limits on the emission indicators of thermal treatment. The emission limits for nitrogen oxides and particulate matter are 30% - 40% lower than those of the old regulations, forcing enterprises to upgrade and transform their equipment, with an additional investment of over 10 million yuan, squeezing the profit space and disrupting the project's rhythm.

- Countermeasures:

Form a policy research team of 5 to 8 people to track the policy dynamics on the official websites of governments at all levels and industry information platforms on a daily basis. Actively participate in 10 to 15 policy discussion and opinion solicitation activities, and jointly voice opinions with industry associations to strive for a favorable policy environment. Adjust the technical plan and calculate costs within 30 days according to policy changes to ensure that the project complies with the new regulations.

2. Regulatory Compliance Risks

- Risk Description:

If the project violates regulations, the penalties can be severe. A single fine for environmental emissions exceeding the standard can reach 500,000 to 1 million yuan. If safety facilities do not meet the standards and cause accidents, the enterprise may face suspension of production and rectification for 3 to 6 months, losing tens of millions of yuan in revenue and may even bear criminal liability. In the thermal treatment process, a 20% fluctuation in the concentration of emissions beyond the national standard may trigger regulatory alarms.

- Countermeasures:

Establish a three-level compliance review mechanism covering the entire process of design, construction, and operation. Regularly invite authoritative third-party institutions to conduct inspection and evaluation to ensure 100% compliance with emission and safety indicators. Organize quarterly training on regulations for all employees, with a training duration of no less than 40 hours, to strengthen

employees' awareness of compliant operations and eliminate potential risks of violations from the source.

4.11 Project effectiveness and attracting investors

I. Project Effectiveness

1. Significant Environmental Benefits

- The automatic plastic waste classification system can accurately separate various plastic wastes from mixed waste, greatly improving the pertinence and efficiency of subsequent treatment. According to actual operation monitoring, the classification accuracy rate can reach over 90%, ensuring that different types of plastic materials can be properly recycled or disposed of, effectively reducing soil pollution and air pollution problems caused by plastic waste landfill and incineration. The thermal treatment technology is a highlight. Through advanced pyrolysis processes, non-recyclable plastics can be converted into reusable resources such as fuel oil, combustible gas, and industrial carbon black, with a conversion rate as high as 70% - 80%, realizing the reduction and resource utilization of plastic waste and helping to improve the local ecological environment.

- For example, after being put into use in a pilot city for one year, the amount of plastic waste sent to landfills decreased by 40%, and the emissions of harmful gases generated by burning plastics were reduced by 30%. The environmental quality of the surrounding soil and water bodies was significantly

improved, injecting a strong impetus into the city's green development.

2. Considerable Economic Benefits

- From the perspective of cost savings, the efficient automatic classification reduces the cost of manual sorting. Compared with traditional manual sorting, labor costs can be saved by about 60% - 70%. The thermal treatment technology turns plastic waste into "treasure from waste". Products such as fuel oil and industrial carbon black produced have a stable market demand and can create additional income for enterprises. Taking a medium-sized treatment equipment as an example, if it can process 5,000 tons of plastic waste annually and produce about 1,000 tons of fuel oil, based on the current market price, the annual income from fuel oil alone can reach 3 to 4 million yuan.

- In addition, this project conforms to the current concept of circular economy. After many enterprises purchase the equipment, they use recycled plastics to produce recycled plastic products. The cost of raw materials is reduced by 20% - 30%, while the added value of products is increased by 10% - 15% due to their green and environmental protection attributes, enabling them to stand out in market competition and driving the economic benefits of the entire upstream and downstream industries.

3. Strong Technological Innovation

- The project integrates cutting-edge machine vision technology and intelligent sensing technology for precise classification. The recognition speed of plastic materials reaches the millisecond level, far exceeding similar products. In

the thermal treatment process, a self-developed high-efficiency pyrolysis and catalysis device is adopted, which optimizes heat transfer efficiency and reaction progress. The energy consumption of the equipment during operation is 25% - 30% lower than that of traditional thermal treatment equipment, ranking at the forefront of the industry. Moreover, the company continues to invest in R&D, applying for 5 - 8 patents every year, continuously iterating and upgrading the technology to maintain the competitiveness of its products and laying a solid foundation for subsequent market expansion and service upgrading.

II. Attracting Investors

1. Huge Market Potential

- The global production of plastic waste is increasing year by year. According to statistics from authoritative institutions, more than 300 million tons of new plastic waste is generated every year, while the recycling and treatment rate is less than 20%, leaving a vast amount of untapped market space. In China, with the full implementation of waste classification policies and increasingly stringent environmental protection requirements, the demand for efficient plastic waste treatment technologies and equipment in various cities is surging. Taking the economically developed regions such as the Yangtze River Delta and the Pearl River Delta as examples, many cities are planning to build new waste treatment plants one after another, and the procurement budget for advanced treatment systems amounts to hundreds of millions of yuan, providing a broad stage for the sales of the products of this project.

- Meanwhile, the international market also has unlimited potential. The plastic industry in Southeast Asia, Africa and other regions is booming, but the waste treatment infrastructure is weak. There is an urgent need to introduce mature technologies and equipment to improve the environment. Relying on its cost-performance advantages and advanced technology, the products of this project are expected to quickly enter the international market, bringing rich return prospects for investors.

2. Diversified Business Models

- Besides equipment sales, the company also launches flexible business models such as equipment leasing, entrusted operation, and revenue sharing. The equipment leasing model reduces the pressure on customers' upfront capital investment, enabling small, medium-sized and micro enterprises to quickly apply advanced technologies. Charges are based on the usage time. The higher the equipment utilization rate, the more 可观 the income. Under the entrusted operation model, the company is responsible for the full-process work such as daily operation and maintenance of the equipment and material treatment. Customers only need to pay the treatment fees, which saves them trouble and effort and ensures the stable and efficient operation of the equipment, enhancing customer stickiness. The revenue sharing model is deeply bound with large plastic recycling enterprises to share the results of plastic waste resource utilization. Revenues are shared proportionally according to the income from recycled products, achieving a win-win situation. Different business models are suitable for

various customer needs, expanding profit growth points and attracting the attention of investors.

3. Professional and Reliable Team

- The project team gathers elite talents in multiple fields such as mechanical design, electronic engineering, materials science, and environmental protection technology. The core members all have more than 10 years of industry experience and have led or participated in the R&D of multiple national-level environmental protection projects, with solid technical strength. The R&D team closely cooperates with many well-known domestic universities and research institutes. The integration of industry, academia, and research accelerates the transformation of technological achievements and injects fresh technological blood every year. The operation team is familiar with market rules and has rich experience in equipment sales, after-sales service, and customer expansion. It can accurately grasp the market pulse and efficiently execute project plans. The professional team provides a solid guarantee for the steady progress of the project and the achievement of expected benefits, greatly enhancing investors' confidence.

4. Strong Policy Support

- As a national strategic emerging industry, the environmental protection industry enjoys many policy preferences. This project conforms to the national orientation of green development and circular economy and can apply for various government special subsidies, such as subsidies for the purchase of environmental protection equipment and funds for scientific and technological innovation awards.

The annual subsidy amount can reach several million yuan. In terms of taxation, enterprises enjoy preferential policies such as "exemption for the first three years and half reduction for the next two years" for enterprise income tax and immediate refund of value-added tax, which greatly reduces operating costs. Some local governments have also set up industrial guidance funds that give priority to investing in such green and environmental protection projects. The favorable policies help the project develop rapidly and reduce investment risks, becoming a key factor in attracting investors.

4.12 Business model of the project

The business model of the Plastic Waste Automatic Classification System and Thermal Machine Processing Technology Project (equipment) of Co., Ltd. encompasses multiple aspects. It collaborates with key partners such as raw material suppliers, scientific research institutions, and equipment integrators. It conducts crucial activities like research and innovation, manufacturing, and pre-sales and after-sales support. The products possess the values of efficient processing, environmental compliance, and economic empowerment. It maintains customer relationships through customized services and community interactions, targeting segmented customer groups such as municipal sanitation departments, waste recycling enterprises, and large factories. It relies on key resources like technical patents, professional talents, and production facilities, and expands sales channels via direct sales teams, industry exhibitions, and online platforms. It has

a cost structure consisting of one-time capital expenditures, fixed costs, and variable costs, and generates revenue streams from equipment sales, after-sales service fees, and technology licensing income. The details are shown in Table 4.9

Table 4.9 Business model of the project

Key partners	Key activities	The value of the offer	Customer Relationship	Consumer segments
- Recycling facilities for plastic waste - Equipment suppliers for thermal processing technology	- Research and development of plastic waste automatic classification system - Operation and maintenance of thermal processing technology	- Efficient and accurate plastic waste classification - Environment friendly	- Provide technical support and training to customers - Regular follow-up on equipment operation and performance	- Municipal waste management departments - Recycling companies
	Key Resources		Sales channels	
	- Patents for plastic waste automatic classification and thermal processing technology - Skilled R & D and technical teams		- Direct sales to waste management departments - Cooperation with recycling companies through industry exhibitions and trade fairs	

Key partners	Key activities	The value of the offer	Customer Relationship	Consumer segments
		thermal processing of plastic waste, reducing pollution		
Cost structure 1.Expenditure one - time (capital): - R & D investment for new technology - Purchase of production equipment 2.The costs are constant - Staff salaries and benefits - Equipment maintenance costs 3.Variable Costs: - Raw material costs for equipment production - Costs of marketing and sales activities			Revenue flows - Revenue from selling plastic waste automatic classification systems - Revenue from providing thermal processing technology services - Royalties from technology licensing	

4.13 Cost

The project mainly includes research and development, logistics. Operating, production and sales costs, specific expenses are shown in the table below

Table 4.10 Breakdown of each cost

Cost Classification	Specific Items	Cost Range (in ten thousand yuan)	Details
R&D Costs	Algorithm Research and Development	150 - 200	Through multiple rounds of tests and optimizations, aiming to steadily increase the recognition accuracy rate of plastic materials from the current 90% to over 95%. Each algorithm iteration test involves more than 50 different plastic samples, and the experimental cycle lasts for 2 - 3 months.
R&D Costs	Thermal Machine Technology Innovation	120 - 180	Purchase advanced thermal simulation analysis software and experimental equipment, and research new pyrolysis and catalysis materials, striving to increase the energy conversion efficiency by 15% - 20%. The R&D and testing costs for new materials alone can reach 30 - 500,000 yuan each time.
R&D Costs	Cooperation Funds	130 - 220	Cooperate with 3 - 5 top domestic universities and research institutes, carry out joint project research, and regularly organize technical exchange seminars, with at least 2 - 3 interactions per month.
Production Costs	Equipment Manufacturing - Production Line	220 - 280	Purchase a full set of automated production equipment. For example, a single high-precision CNC machining

Cost Classification	Specific Items	Cost Range (in ten thousand yuan)	Details
	Equipment Purchase		center costs more than 800,000 yuan, and the installation of an intelligent automation control system costs about 600,000 - 900,000 yuan.
Production Costs	Equipment Manufacturing - Conveyor Belt	20 - 30	The specially made high-strength and corrosion-resistant conveyor belt costs 3,000 - 5,000 yuan per meter, and the laying cost of a complete production line conveyor belt is approximately within this range.
Production Costs	Equipment Manufacturing - Intelligent Sorting Device	80 - 120	Integrated with advanced visual recognition modules and robotic arms, each set of cost is within this range.
Production Costs	Equipment Manufacturing - Combustion Chamber	90 - 130	The advanced combustion chamber of the thermal treatment equipment is made of special alloy materials, and the construction cost is within this range.
Production Costs	Equipment Manufacturing - Heat Exchanger	70 - 100	The high-efficiency heat exchanger uses imported heat exchange tubes, and the cost is within this range.
Production Costs	Equipment Manufacturing - Temperature Control System	40 - 60	The procurement and commissioning costs of the high-precision temperature control system are approximately within this range.
Production Costs	Parts Procurement - Plastic Recognition Sensors	96 - 180	Imported from international renowned manufacturers, each set has a procurement price of 120,000 - 180,000 yuan, and 8 - 10 sets are required for a medium-sized production line.

Cost Classification	Specific Items	Cost Range (in ten thousand yuan)	Details
Production Costs	Parts Procurement - Special Ceramic Materials	80 - 180	The heat-resistant and corrosion-resistant special ceramic materials in the thermal equipment cost 80,000 - 120,000 yuan per ton, with a usage of about 10 - 15 tons.
Production Costs	Parts Procurement - Conventional Parts	30 - 50	The total procurement costs of various electrical control components, fastening connectors and other conventional parts.
Production Costs	Assembly - Labor Cost	15 - 22	Skilled assembly workers have a daily wage of 500 - 800 yuan, and it takes 30 - 40 working days to assemble a medium-sized set of equipment.
Production Costs	Assembly - Quality Inspection Cost	5 - 8	Professional flaw detectors, precision testers and other equipment are used. The equipment purchase and maintenance costs exceed 300,000 yuan, and the cost of consumables and labor for a single quality inspection and testing is approximately within this range.
Operational Costs	Technical Support - Salary	240 - 540	The technical support team consists of 20 - 30 people, with an annual salary per person of 120,000 - 180,000 yuan.
Operational Costs	Technical Support - Operation, Maintenance and Inspection Expenses	50 - 80	The annual cost of daily operation and maintenance tools and spare parts reserves is 300,000 - 500,000 yuan. Regular inspections of equipment involve monthly trips exceeding 5,000 kilometers, with vehicle wear and tear, travel expenses, etc. amounting to about 200,000 - 300,000 yuan.

Cost Classification	Specific Items	Cost Range (in ten thousand yuan)	Details
Operational Costs	Customer Service - Labor Cost	120 - 240	The customer service team consists of 15 - 20 people, with an annual salary per person of 80,000 - 120,000 yuan.
Operational Costs	Customer Service - Training Materials and Platform Expenses	18 - 27	The carefully prepared customer training materials cost 100,000 - 150,000 yuan. The server rental and software maintenance fees for operating the online customer service platform are 80,000 - 120,000 yuan per year.
Operational Costs	Customer Service - Call Center Expenses	5 - 10	The call center is equipped with professional telecommunication equipment, and the procurement and phone bill expenses are approximately within this range.
Operational Costs	Market Expansion - Exhibition Expenses	69 - 111	Select 3 - 5 domestic and international large-scale environmental protection exhibitions to participate in each year. The rental and decoration costs of a single booth are 150,000 - 250,000 yuan, and the transportation and installation costs of exhibits and labor costs are about 80,000 - 120,000 yuan, with a total cost of 230,000 - 370,000 yuan per exhibition.
Operational Costs	Market Expansion - Magazine Advertising Expenses	30 - 75	Advertise in industry-authoritative magazines. The price for a full-page color advertisement is 30,000 - 50,000 yuan per time, and 10 - 15 times of placement are made throughout the year.
Operational Costs	Market Expansion - Offline	80 - 150	Conduct offline promotion activities in key regions. The costs for materials production, venue rental, and personnel

Cost Classification	Specific Items	Cost Range (in ten thousand yuan)	Details
	Promotion Expenses		travel, etc. are 100,000 - 150,000 yuan each time, and 8 - 10 times of activities are held in a year.
Sales Costs	Sales Team Salary	400 - 600	The sales team consists of 30 - 40 people, including regional sales managers (with an annual salary of 250,000 - 350,000 yuan), sales representatives (with a basic salary of 120,000 - 180,000 yuan), and key account representatives (with an annual salary of 200,000 - 300,000 yuan).
Sales Costs	Advertising and Promotion - Online Advertising	120 - 180	Place information flow advertisements on leading industry websites and social media platforms, with an annual advertising budget within this range.
Sales Costs	Advertising and Promotion - Offline Materials	60 - 150	Produce promotional posters and product brochures, with a unit cost of 3 - 5 yuan, and print 200,000 - 300,000 copies per year.
Sales Costs	Advertising and Promotion - Video Production	30 - 50	Customize corporate promotional videos, with shooting and editing costs within this range.
Sales Costs	Channel Development - Research and Negotiation	20 - 30	To explore high-quality agents, the travel expenses for market research and business negotiations in the early stage are within this range.
Sales Costs	Channel Development - Training Expenses	15 - 25	After signing contracts, provide professional training for agents, hire internal and external lecturers, and the costs for curriculum design, training venue rental, etc. are within this range.

Cost Classification	Specific Items	Cost Range (in ten thousand yuan)	Details
Sales Costs	Channel Development - Incentive Expenses	80 - 120	Formulate channel incentive policies, and give a rebate reward of 5% - 10% based on sales performance, with an estimated annual incentive expenditure within this range.
Logistics Costs	Equipment Transportation - Within 500 Kilometers	1.125 - 2	For domestic transportation, when the distance is within 500 kilometers, the freight per ton-kilometer is 1.5 - 2 yuan, and a medium-sized set of equipment weighs 15 - 20 tons.
Logistics Costs	Equipment Transportation - 1000 Kilometers	3 - 4.5	When the transportation distance is 1000 kilometers, the freight per ton-kilometer is 2 - 3 yuan, and a medium-sized set of equipment weighs 15 - 20 tons.
Logistics Costs	Equipment Transportation - Over 2000 Kilometers	9 - 16	For long-distance transportation over 2000 kilometers, the freight per ton-kilometer is 3 - 4 yuan, and a medium-sized set of equipment weighs 15 - 20 tons.
Logistics Costs	Equipment Transportation - To Europe and America	25 - 40	For international transportation to Europe and America, the transportation cost of a set of equipment is within this range.
Logistics Costs	Equipment Transportation - To Southeast Asia	15 - 25	For international transportation to Southeast Asia, the transportation cost of a set of equipment is within this range.
Logistics Costs	Waste Plastic Recovery - Small and Medium Scale	36 - 60	When the annual recovery volume is 5,000 - 8,000 tons, cooperate with surrounding cities, rent medium-sized freight vehicles, with a single freight cost

Cost Classification	Specific Items	Cost Range (in ten thousand yuan)	Details
			of 3,000 - 5,000 yuan, and transport 20 - 30 trips per month.
Logistics Costs	Waste Plastic Recovery - Large Scale	80 - 120	When expanding the long-distance recovery business and the annual recovery volume exceeds 10,000 tons, purchase large-scale dedicated transport vehicles, each costing 800,000 - 1,200,000 yuan, along with drivers and maintenance.

4.14 Conclusions for startup project

Overall, the start-up conditions for Guangdong Yuekong Electric Co., Ltd's plastic waste automatic classification system and thermal treatment technology project are mature and complete. Technologically, it has outstanding advantages, the market potential is huge, the financial guarantee is strong, and the degree of conformity with policies and regulations is high. Although there are still potential challenges such as slight technological adjustments and intensified market competition, as long as the innovation-driven and flexible response strategies are adhered to, the project can be successfully launched, operate stably and achieve the expected benefits in the near future. It is expected to grow into a benchmark project in the field of plastic waste treatment and contribute outstanding strength to the development of the environmental protection industry.

Conclusion

Plastic recycling plays a crucial role in promoting the development of a circular economy and is the key path to solving the current plastic pollution problem and achieving sustainable resource utilization. Through an in-depth analysis of the current status of plastic waste, the electromechanical equipment automated plastic waste sorting system, the company's plastic waste disposal technology, and the challenges faced and the corresponding countermeasures, this paper comprehensively presents the complex status quo and future development direction of the plastic recycling field.

Plastic waste has become an environmental problem that urgently needs to be solved on a global scale. Its production continues to increase, but the recycling rate is relatively low. A large amount of plastic waste accumulates in the natural environment, causing serious damage to the marine ecosystem and threatening the survival of many marine organisms. Plastics in the ocean not only cause entanglement and suffocation of organisms but also decompose to form microplastics, which enter the human body through the food chain and endanger human health. In the urban environment, plastic waste also brings many negative impacts, such as affecting the city's appearance, clogging drainage pipes, and polluting water bodies. In China, a country with a large population and rapid economic development, the problem of urban plastic waste is particularly prominent. Traditional treatment methods such as landfilling and incineration have

many drawbacks, and the recycling system also needs to be improved, which further exacerbates the pressure of plastic waste on the environment.

Guangdong Yuekong Electric Co., Ltd. has shown an active spirit of exploration and innovation in the field of plastic waste treatment. Its electromechanical equipment automated plastic waste sorting system integrates advanced technical concepts and realizes the efficient sorting and recycling of plastic waste through the close cooperation of vision, transmission, and grasping modules. The carefully selected cameras, lenses, and light sources in the vision module ensure the high quality of image acquisition and provide a solid foundation for accurate identification; the reasonable design of the transmission module, including the appropriate conveyor belt, motor, encoder, and frequency converter, ensures the stable transportation and speed control of materials; the industrial robots selected in the grasping module and the uniquely designed high-pressure air injection end effector effectively improve the grasping efficiency and accuracy. The meticulous consideration in the hardware selection of this system fully reflects the company's pursuit of improving system performance, enabling it to effectively deal with complex and diverse plastic waste in practical applications and achieve a relatively high classification accuracy, providing strong support for subsequent recycling and treatment.

The company's plastic waste disposal technology adopts the pyrolysis process and has achieved certain positive results in the treatment of plastic waste. The pyrolysis process can convert plastic waste into potentially valuable resources

such as oil, gas, and carbon black. This treatment method stands out among many waste treatment methods and is regarded as a relatively ultimate solution. However, the pyrolysis technology is not without challenges. During the pyrolysis process, due to the complex composition of plastic waste, a variety of harmful gases such as hydrogen chloride, ammonia, and hydrogen sulfide will be produced, and the emission of these gases poses a serious threat to the environment and human health. In addition, the complexity of plastic waste itself, such as uneven composition and diverse structures, also brings difficulties to the optimization of the pyrolysis technology and requires further in-depth research and improvement.

Facing the many challenges in the plastic recycling field, Yuekong Electric Co., Ltd. has actively responded and taken a series of targeted measures. In terms of technical challenges, the company is committed to the development and optimization of algorithms, using deep learning technology to improve the recognition ability of complex plastic waste; integrating multimodal sensing technology and realizing more accurate classification through the comprehensive analysis of multiple sensor data; at the same time, regularly upgrading equipment and optimizing parameters to ensure that the equipment performance meets the continuously increasing classification requirements. In terms of harmful gas emission control, the company cooperates with scientific research institutions to improve the pyrolysis technology, develop new catalysts to reduce the generation of harmful gases; install advanced gas purification equipment and establish a real-time monitoring system to ensure that the emission of harmful gases meets the

standards; strengthen process monitoring and personnel management to ensure the environmental protection and stability of the treatment process.

Although Yuekong Electric Co., Ltd. has achieved certain results in plastic recycling technology and treatment systems, the overall plastic recycling industry still faces many difficulties. At the technical level, problems such as improving classification accuracy and dealing with complex plastic types still need to be continuously overcome; economically, issues such as cost control, long investment return periods, and market competition pressure need to be urgently addressed; the regulatory environment is becoming increasingly strict, requiring enterprises to continuously ensure compliance operations; market competition is becoming increasingly fierce, and enterprises need to continuously improve their core competitiveness; the instability of the supply chain and the pressure of technology updates and personnel training also pose challenges to enterprise development.

Looking to the future, the plastic recycling industry is full of opportunities and challenges. With the continuous progress of science and technology, it is expected that more efficient and environmentally friendly recycling technologies will be developed, further improving the efficiency and quality of plastic recycling, realizing the resource utilization, reduction, and harmless treatment of plastic waste, and thus promoting the healthy development of the circular economy. Enterprises should continue to increase R & D investment, strengthen technological innovation, and actively respond to market changes; the government

should strengthen policy guidance and support, improve relevant laws and regulations, and promote the sound development of the recycling system; all sectors of society should also enhance environmental awareness and jointly participate in plastic recycling actions. Only through the joint efforts and cooperation of all parties can the severe environmental challenges brought by plastic waste be effectively addressed and the sustainable utilization of resources and the protection of the ecological environment be achieved.

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