An Efficient Broken Glass Sorting Device Based on Color Detection and Human-Machine Interactive

Lingyu Liao*, Yifan Wu
School of Mechanical and Electrical Engineering, Wuhan University of Technology, Wuhan, China

*Corresponding author: cailanlan@whut.edu.cn

Abstract. With the increasing production of wasted glass in China, the recycling of glass is becoming more and more significant. Recycled broken glass must be color-recycled, and the key issues for color separation of glass are color recognition and sorting of glass in different color. Utilizing the TCS3200D color sensor to distinguish the color of broken glass and setting the algorithm according to its optical characteristics, as well as using a mechanical module with vibration separation, to export broken glass to the conveyor belt in order, and then by the ordering of MCU, pneumatic solenoid valve control the high-pressure jet device to sort the broken glass. At the same time, the human-computer interactive image processing technology based developed by LabVIEW is used to set up the human-computer interactive interface, so as to maximize recycling.

1. Introduction
With the continual development of China's glass manufacturing industry, the output of used glass is increasing, which makes the recycling of used glass become more and more significant. China produces up to 50 million tons of used glass every year while the recycling rate of wasted is less than 25%. The core problem that gives rise to the unsatisfactory of glass recycling rate is that glass recycling requires broken glass to be sorted out in different colors so that it can be reused. During the recycling process of wasted glass, in order to ensure the color, purity and other requirements of recycled products, it is required to separate the glass in different colors before. Contemporarily, existing device of glass color separation module requires complex image recognition device, which ought to be blamed for the unaffordable cost. Meanwhile, because the waste glass is often stacked, the separation efficiency and the response rate of the device need to be improved. Be aimed at solving the technical problems of difficulties on color selection and unsatisfied recycling rate, a broken glass sorting device based on TCS3200D sensor and human-machine interaction module is discussed in this paper.

2. Device structure and function
This design is designed to solve the problem of waste glass separation recognition by designing a vibration-type single separation module, sorting module and human-computer interaction module integration device. The overall unit is about 3m long, 1m high and 0.5m wide. The device is mainly divided into four modules. The first module is a vibrating single separation module, which can make broken glass pass through in a single and orderly way, and realize the single and effective separation
and detection of waste glass. Secondly, the object color detection module based on TCS3200D sensor can automatically recognizes the corresponding color of the object. The third is the compressed air sorting module. In the process of the broken glass moving on the conveyor belt, the glass of specific color will be acted upon by the high-speed jet device at a specific position and enter the respective collection device through the converted signal of color recognition. The fourth is the man-machine interaction module, which is used for the device to submit to send the user the amount of waste glass collected in each color, to view the pictures of broken glass that cannot be recognized, and to control the color sorting by the user.

Figure 1. The overall unit.

Figure 2. Device flowchart.

2.1. Vibration separation module
Vibrating separation module is composed of intermittently feeding mechanism, vibration transfer module, and single glass transmission module.

Figure 3. A diagram of the vibration separation module.
2.1.1. Intermittently feeding mechanism. Intermittently feeding mechanism achieve batch feeding when a large amount of broken glass was input, through the action of cone gear mechanism, gear and flank mechanism, the module controls the intermittent time of slope plate moving up and down, that is, controls the amount of a sole period of feeding, which can limit the feeding quantity and speed, in order to avert congestion, to achieve a constant speed of feed.

![Figure 4. A diagram of the intermittent feeding module.](image)

2.1.2. Vibration transfer module. Vibration transfer module was located behind the intermittent feeding module. In order to convert accumulation state into single layer state, broken glass was spread out with the vibration and accumulation parts are also knocked down after entering the module. After vibration, the height limit part at the outlet allows a single layer of glass to be output.

2.1.3. Single glass transmission module. Single glass transmission module is composed of three vibration plates with the longest length of a single glass. Both the left, middle and right plates are concatenated by rotating shafts so that every plant can rotate flexibly. The end of middle plate is designed to formation an exit connecting the conveyor belt. After the broken glass on the middle plate leads to the conveyor belt for further testing, the left and right plates rotate into a slope so that the subsequent broken glass falls on the middle plate. Through several cycle can a single delivery of all the broken glass be output.

![Figure 5. A brief diagram of the three-plate vibration mechanism.](image)

2.1.4. Effect of vibration separation module. Vibration separation module converts the broken glass from the original accumulation state into a single, orderly, uniform state to output. It ensures that glass can fall in sequence along the track and enter the detection area in an orderly manner and be instantly unique when passing through the camera section of the detection area. Meanwhile, it ensures the period that each piece of broken glass takes from the inspection area to the sorting area is a relatively stable constant so that the sorting device is accurately sorted.

2.2. Color detection module

The color detection module of device consists of a SCM, a color sensor and an external drive mechanism. Taking into account the overall cost and function of the unit, the module uses the STC89C52 singlechip microcomputer and TCS3200D sensor produced by TAOS as the color sensor. The relay which controls sorting module that controls the compressed air is connected to the I/O port of the microcomputer, and driven by the current amplified by the audion. The relay is used to control the circuit which drives the external generates the air jet.

The STC89C52 microcontroller obtains the signal reflecting color of glass pieces by converts detecting the frequency of square wave from OUT pin of the TCS3200D sensor and the level of S2 and
S3 pins into data in RGB format for judgment. When the color of the object is compared with the reference color already set to detect, the output detection results if the two colors match within a certain error range. The TCS3200D sensor outputs the color signal by changing the frequency of the output signal as follows:

\[
R = 255.0 \times \frac{n_R}{n_{WR}} \tag{1}
\]

\[
G = 255.0 \times \frac{n_G}{n_{WG}} \tag{2}
\]

\[
B = 255.0 \times \frac{n_B}{n_{WB}} \tag{3}
\]

Including \(n_R, n_G, n_B\) for the number of pulses that SCM receives in unit time from the sensor, \(n_{WR}, n_{WG}, n_{WB}\) for the number of pulses that SCM receives in unit time from the sensor in the scene with white background light, which were preset. The RGB color data of small glass piece can be obtained by the program in SCM through the formula above.

In the formula above, \(n_R, n_G, n_B\) represent the number of pulses received by SCM in unit time from the sensor, \(n_{WR}, n_{WG}, n_{WB}\) represent the number of pulses received by SCM in unit time from the sensor in a white background light scene, which were set in advance. The RGB color data of small glass pieces can be obtained by the program in SCM through the formula above.

2.3. Sorting module

Sorting module is installed after the vibration separation module and consists of a conveyor belt at a fixed speed and an air jet device. The conveyor belt is used to continuously direct the piece of broken glass at a fixed speed for subsequent sorting operations. Each conveyor belt of the module is fitted with 4 sorting points to sort flint, cranberry, green and other colored glass. The air jets are installed in pairs with the sorting port and are used to blow the small piece of glass into the corresponding sorting port after obtaining the instructions from SCM.

When working, the signal detected by the sensor is shaped, amplified and transmitted to the judgment circuit, which can divide the resulting into two types of signal and transmit it to the microcontroller system. The microcontroller system can transform the light pulse signal into the power pulse signal to control the solenoid valve, so as to achieve the sorting function. After obtaining the color information of the small glass piece from the sensor, the SCM determines the sorting type of the glass through the

Figure 6. A diagram of the control circuit.
procedure, calculates the time of glass passing through the sorting port according to the speed of the conveyor belt and the position of the sorting port, as well as being activated the relay when the glass passes. The air jet device is controlled to blow the small glass pieces into the corresponding sorting port to complete the sorting recovery process according to colors.

![Figure 7. TCS3200D basic functional block diagram.](image1)

![Figure 8. A diagram of the structure of the sorting module.](image2)

2.4. Human-machine interaction module
With interactive interface designed with LabVIEW, users can get feedback and photos of broken glass that have not been recognized in real time, so as to timely check the sorting situation. Meanwhile, the interactive interface would display the number of jetting at four sorting points and glass collected quantity by color in real time. Users can adjust the color of broken glass sorted by the four jets on the interface, so as to manage glass recycling in different situations. With human-machine interaction module, the devise can maximize the recovery and utilization of colored glass under different conditions, without wasting or giving up all kinds of colored glass.

3. Research basis and feasibility analysis of the project

3.1. Research base and feasibility
TCS3200D has been widely used for color signal acquisition. Due to the complexity of color signal itself, one color is synthesized by many colors in different proportions. Colors in nature are composed of red, green, and blue. Therefore, the detection of color is actually equivalent to the detection of the
ratio value of red, green and blue. The programmable optical frequency converter TCS3200D introduced by TAOS can realize color recognition and detection. Compared with the traditional color sensor, it has many excellent features: fast response speed, software Settings can be used to change the choice of color; The output is digital signal, which is easy to use and has strong anti-interference ability. Can collect and amplify signals; A/D interface is integrated, and the output signal is a series of square wave signals, which can be directly transmitted to SCM.

![TCS3200D pin diagram.](image)

The object color recognition module of this device recognizes the color of glass through the sensor, so as to process the color of glass separately. At present, China's color recognition technology has been greatly developed, and the efficiency of air jet flow can reach 95%. Assuming that the speed of conveyor belt is 1m/s and the length of conveyor belt is about 0.5m, the device can handle 1t of glass in half a day, with considerable efficiency. Therefore, the object color detection module of this product realizes the function of recognizing different colors of glass through sensors, which is technically feasible.

3.2. Application foreground analysis

At present, the average recycling rate of waste glass in Western European countries has reached 30.5%. The EU member states plan to increase the recycling rate of all kinds of waste glass by one time within 2~3 years. The measure is estimated to save 25 million liters of oil, 2 million tons of raw materials, 20 million marks ($11.84 million) in waste disposal costs and 20 percent less waste glass in garbage. At present, the discharge of waste glass as well as to be recycled, glass factory and recycling waste glass processing sites and other places is focus on the main location, usually glass factory buy as raw materials of glass waste glass, waste disposal site for glass of environmental pollution by landfill or burned headache, if will old glass recycling up can greatly promote the economic development, reducing environmental pollution, so this device can be used in glass production and recycling waste glass processing site centralized locations. In the past three years, the price of glass per ton is between 1200 and 1700 yuan, and it is increasing year by year. The production and economic value of glass also provide a good social foundation for the utilization of glass recycling.

Modern domestic glass enterprises can generally be divided into the following forms of broken glass recovery: all artificial, artificial assistance, full machinery, etc., but the early stage has not been sorted color or manual simple sorting, low efficiency, low recovery. There are few kinds of color sorters in China, most of which are for corn, soybean and other grain color screening, but not for broken glass sorting. Moreover, due to the failure to achieve a single separation of feeding materials, the machinery used in sorting is expensive, resulting in waste glass recycling in China has been in a state of waste and pollution of the environment.

Therefore, to develop a man-machine interactive device based on sensor TCS3200D color sorting was carried out on the broken glass packaging device, effectively increase the recycling of waste glass, solves the problem of environmental pollution, but also can increase the economic benefits of broken glass processing plant and glass factory, has the good economic efficiency and energy conservation and emissions reduction benefits.
4. Project innovations

4.1. Structural innovation
A single vibrating separation module is designed. The three-in-one vibrating plate controls the tilt and time of the left and right plates, so that the broken glass can be separated in a single and orderly way through the conveyor belt.

4.2. Functional innovation
TCS3200D color sensor is used to realize the color recognition of broken glass, and the algorithm is set for the optical characteristics of broken glass to improve the resolution and achieve efficient recognition and recovery.

4.3. Application innovation
The man-machine interaction module is applied to the color sorting of broken glass, which is highly operable and users can freely set and change the desired color of glass.

5. Conclusions
To sum up, the broken glass sorting device based on color detection and human-machine interactive described in this paper not only effectively solves the problem of environmental pollution, but can also save raw materials in glass manufacturing process, playing the role of energy conservation and environmental protection since it can effectively reduce fuel combustion and carbon emissions. The device can also develop many additional functions in the future, and its main functions can also be improved to make it more integrated, multi-adaptability, security. It has extremely outstanding advantages with a very broad application prospect.

Acknowledgments
National innovation and entrepreneurship training program for college students S202010497074

References
[1] Di Leigang. Recycling and reuse of waste glass [J]. Glass, 2019, 46(06): 52-55.
[2] Waste glass processing equipment of Binder+Co. [J]. Glass and enamel, 2009, 37(05): 47-49.
[3] Shi Yangyang, Xu Chang, Chen Xi, Wu Wenming. Structure and Data Analysis based on TCS3200 Sensor [J]. Science and Technology Innovation, 2017(22): 52-53.