Automatic Storage System Based on Weight and Volume Measurement

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Abstract. In order to cope with the current mixed production of small and medium-sized enterprises, the production mode with many styles and few quantities leads to the problems of low labor efficiency and easy to make mistakes. I put forward a research scheme of warehouse control system based on volume and weight measurement, which adopts automation technology and information technology. My research ideas are: from the volume, weight, the first is to transport goods on the conveyor belt; Goods through barcode scanner for information entry and statistics; Then the volume and weight are measured automatically. If the quantity is large and easy to distinguish, the goods will be transferred directly from the assembly line. If the quantity is small and difficult to distinguish and easy to make mistakes, the controller will assign the storage location and store it in the warehouse. Finally, manage the capacity of each location and manage the outbound. The experiment proves that it can save human resources, ensure operation efficiency and accuracy, reduce costs and improve the level of warehouse information and intelligence.

Keywords: Mixed flow production, volume&weight measurement, automatic storage.

1. Introduction

With the change of manufacturing environment, the production of products gradually changes from the original single-variety production mode to multi-variety mixed production mode, multiple products run on the same production line at the same time, and are separated only after reaching the sorting line [1]. The product cycle is getting shorter and shorter, the production mode of various small quantities [2] is becoming more and more demanding, and the quantity of these goods is small and mixed with large quantities of goods, either the volume is similar but the weight is different, or the weight is similar to the volume is different. In order to solve the existing problems of sorting and storage of goods that are small in quantity but need manpower, but still have human error, first identify and sort out the goods that are small and difficult to distinguish.

Storage plays an important role in enterprises. Currently, intelligent storage adopts RFID technology [3] and Internet of things technology [4], which brings more convenient operation for enterprises' production decisions. "Internet + logistics" has become an important development mode of logistics industry [5]. The intelligent storage management system built by Shuikou group realizes unattended material collection [6]. Nowadays, AGV[7], electronic label or bar code printer and scanning equipment...
are widely used in storage, and the cost is relatively high. As the name implies, intelligent storage based on volume and weight means measuring according to volume and weight without electronic labels, bar code printers, bar code scanners and other devices. After the goods are delivered to the feeding unit, they pass through the volume and weight detection module successively through the conveyor belt, and then carry out information matching and condition judgment. The controller performs warehouse location allocation and optimal path storage operation.

2. The Hardware Design
The automatic storage system based on weight and volume measurement is divided into four modules: conveying module, detection module, storage module and inventory management module.

2.1. Testing Organization

2.1.1. Gravimetric Mechanism. Weight measurement is a dynamic and fast process, and the time for the object to be tested to pass through the weight area is usually only a few hundred milliseconds. Therefore, the weight sensor not only requires high precision and strong anti-interference ability, but also requires relatively fast response speed. Therefore, a pressure - varying resistance type weighing sensor with high sensitivity and mature technology is selected.

2.1.2. System Modeling.

![Figure 1. Dynamic weighing model](image)

The dynamic model of the weighing sensor can be simplified as shown in Fig 1. $k$ is elastic stiffness ($N/m^2$), $c$ is damping constant ($N/m^2$), $m_0$ is the equivalent mass of the sensor itself, $G$ is the weight of the object being weighed. Usually the mass of the base is so large that it is considered stationary. Since the bracket and the weight are not fixed, two equations are needed to describe the dynamic characteristics of the above system.

Set the force between $m$ and $m_0$ as $f$, and there is no relative motion between them, then:

$$\left( m + m_0 \right) \frac{d^2 x}{dt^2} + c \frac{dx}{dt} + kx = G$$

The compensator model is:

$$H_{bc}(s) = \frac{s^2 + 2ak_n + k_n^2}{s^2 + 2k_n s + k_n^2}$$

The simulation results of compensation effect are shown in Fig 2, it is proved that the parameters of dynamic compensator can automatically track the changes of sensor model, ensuring the rapid response of measurement system from start to finish.
2.2. **Volumetric Mechanism**

Three sets of measuring light screens are adopted for volume measurement, and the length, width and height of items are measured, and then the data are sent to the upper computer respectively to calculate the volume of items to be measured by means of cross section accumulation.

For the cube $L=25.5$cm, $W=16.0$cm, $H=8.2$cm, $V = L \cdot W \cdot H = 3345.6$cm$^3$ measuring data are shown in table 2 as follows: ($L$: Length; $W$: Width; $H$: Height; $V$: Volume).

Table 1 shows the error between the fitting weight and the real weight. The hourly weight deviation error is relatively large, and the overall average error is about 1.32%, which meets the accuracy requirement of ±5% of the weight measurement system.

**Table 1. Error table**

| Serial number | Actual weight (g) | Fitting weight (g) | Error  |
|---------------|------------------|-------------------|--------|
| 1             | 370.5            | 383.8             | 3.59%  |
| 2             | 785.8            | 765.9             | 2.53%  |
| 3             | 1007.6           | 993.3             | 1.42%  |
| 4             | 1342.6           | 1332.4            | 0.76%  |
| 5             | 1629.1           | 1645.6            | 1.01%  |
| 6             | 1816.5           | 1803.7            | 0.70%  |
| 7             | 2093.1           | 2125              | 1.52%  |
| 8             | 2340.9           | 2336.3            | 0.20%  |
| 9             | 2597.2           | 2632.5            | 1.36%  |
| 10            | 2907.8           | 2889.2            | 0.64%  |
| 11            | 3116.1           | 3091.1            | 0.80%  |

**Average Error**

1.32%
Table 2. Data measurement results of cubes

| Serial Number | L/cm | W/cm | H/cm | V/cm³ |
|---------------|------|------|------|-------|
| 1             | 25.58| 15.98| 8.14 | 3327.38 |
| 2             | 25.6 | 15.96| 8.2  | 3350.32 |
| 3             | 25.53| 15.98| 8.21 | 3349.43 |
| 4             | 25.48| 15.99| 8.14 | 3316.44 |
| 5             | 25.52| 15.94| 8.04 | 3270.58 |
| 6             | 25.35| 16.02| 8.09 | 3285.41 |
| 7             | 25.54| 15.99| 8.19 | 3344.67 |
| 8             | 25.4 | 15.81| 8.21 | 3296.92 |
| 9             | 25.6 | 15.99| 8.18 | 3348.43 |
| 10            | 25.39| 15.98| 8.15 | 3306.72 |
| Mean          | 25.499| 15.964| 8.155| 3319.63 |
| Average Error | 0.004%| 0.23% | 0.55% | 0.78% |

The average relative error of volume is less than 1%, which meets the set requirements of volume threshold ±2% and can meet the requirements of measurement accuracy.

3. Storage Module
After measurement of volume and weight, the storage location of items is determined, and the actuating mechanism is driven to separate different items in an optimal path, so as to achieve the purpose of automatic sorting and storage of items. The following principles are adopted:

a) The principle of nearest storage: storage shall be carried out according to the storage location closest to the initial position of the access claw.

b) The principle of zero storage and lump-sum withdrawal.

c) Underlying priority principle.

d) First-generation principle.

4. Analysis of Experimental Results
500 measurement experiments were carried out for each of the three groups of experimental subjects, and the recognition rate was compared, as shown in table 3:

Table 3. Recognition rate comparison

| Serial Number | Length | Width | Height | Weight | Volume | Weight | Volume& Weight | Recognition Rate |
|---------------|--------|-------|--------|--------|--------|--------|----------------|------------------|
| 1             | 20 cm  | 10 cm | 10 cm  | 2000 g | 85%    | 92%    | 97%            |                  |
| 2             | 20 cm  | 10 cm | 10 cm  | 3000 g | 86%    | 91%    | 98.50%         |                  |
| 3             | 20 cm  | 15 cm | 10 cm  | 2000 g | 87%    | 94%    | 98%            |                  |

As can be seen from table 3, which verifies the validity and accuracy of volume and weight measurement. It can be seen from the data of 1 and 2 or the data of 1 and 3, simple weight or volume measurement has its limitations. While the dual feature recognition based on volume and weight has high accuracy, it can quickly and accurately identify artificial objects that are difficult to distinguish, so it is feasible.

5. Conclusion
Automatic storage system based on weight and volume measurement by the volume and weight measuring system combined with each other, the two characteristics measured, can be real-time and accurate quickly identify artificial is difficult to distinguish between items, intelligent sorting inventory, product information, achieve automatic detection and identification of product, sorting, transport and storage, and people just for the placement of the goods, to improve the production efficiency. Save manpower and reduce production cost.

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