Design of integrated metal packaging container performance parameter detection device

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Abstract. An integrated container performance parameter testing device is developed for the packaging container with metal as material. It is suitable for the comprehensive performance test of the metal packaging container, and can realize the rapid and accurate measurement of the volume, sealing, vacuum degree and pressure strength of the metal packaging container. This paper introduces the working principle, hardware structure, software system and testing function of the device. The hardware system is composed of differential pressure sensor, absolute pressure sensor, temperature sensor, mass flow controller and USB-2611 high speed acquisition card. The application program of data acquisition and processing based on LabVIEW is designed. This system can realize the function of collecting, storing, real-time displaying and processing analysis. The experimental results show that the device can measure the volume, sealing, vacuum and compressive strength of metal packaging container quickly and accurately.

1. Introduction

Metal packaging container is a thin walled package of container made of metal. It is widely used in food packaging, pharmaceutical packaging, daily necessities packaging, instrument packaging, industrial packaging, arms packaging and so on, among them, the number of food packages is the largest. The metal packaging tank products are mainly iron metal packaging cans, two or three pieces of beverage cans, milk powder cans, ordinary food cans, aerosol cans, crown cover, spinning cover, easy to pull cover, mixed cans, chemical cans, 200 liters of steel barrel and so on. Most of the materials used in metal packaging cans are steel and aluminum, and the steel products are mainly low carbon steel sheets and tinplate (commonly known as tinplate), tin free steel sheet (chrome-plating steel sheet), white iron sheet (galvanized steel sheet), coated steel plate, the coating iron, aluminium products include aluminium plate, aluminium foil, aluminized film and so on.

Steam penetrates through the metal with low efficiency and completely opaque. It can effectively avoid the harmful effects of ultraviolet radiation. Its gas-resisting, humidity-preventing, shading and fragrance-holding greatly exceed plastic, paper and other types of packaging materials. Therefore, metal packaging can maintain the quality of products for a long time.

The volume of the metal packing container is more difficult to measure by the irregular edge shape control such as rolling rib; the compressive strength determines the stacking of packing containers during storage and transportation, height further affects the cost of storage and transportation. Vacuum degree is an important index to measure the performance of vacuum packaging equipment; tightness
determines the expiration date of the goods. At present, the equipment for detecting the above container parameters is mainly empty tank side leakage meter, tank body axial bearing pressure tester and vacuum side leakage meter, limited by various conditions, these devices have a single function and limited application range, and can not realize the unified measurement of the volume, sealing, vacuum degree and pressure strength of the metal packing container. Therefore, based on the characteristics of metal packaging containers, this paper has developed an integrated testing device for the performance parameters of the metal packaging container, which can realize the rapid and accurate measurement of the volume, sealing, vacuum degree and pressure strength of the metal packaging container.

2. Structure design of integrated metal packaging container performance parameter detection device

2.1. Overall structure design

The integrated testing device for metal packaging container is mainly composed of the test chamber, the bellows seal assembly, the top rod, the precision piston and so on. The major structure is shown in Figure 1.

![Figure 1](image)

1- Base; 2- Screw seat; 3- High precision screw; 4- Bellows seal assembly; 5- Test sensor; 6- Sensor interface; 7- Test chamber

**Figure 1.** Diagram of the device for detecting the performance parameters of integrated metal packaging containers

The metal packaging container testing device is designed according to the design criteria of the vacuum pressure vessel, and many sensor interfaces are reserved. The overall leakage rate of the test device after assembly is less than $2.6 \times 10^{-11}$Pa m$^3$/s. The components can be replaced according to the contents of the measurement, and a variety of parameters can be measured.

2.2. Design of bellows seal assembly

The vacuum degree test of the metal packing container needs to make the packaging container damaged in the test chamber, release the vacuum degree in the packing container, and get the vacuum degree in the packing container by measuring the pressure change in the cavity. This testing method requires an external intervention to break the metal packaging container in a closed test chamber. A method for the use of the axial flexibility of a high vacuum welded bellows is proposed, as shown in Figure 2.
1. Sealing flange 2. CF50 High vacuum flange 3. High vacuum welded bellows 4. CF50 Blind flange 5. rod sleeve 6. rod 7. Connected hole

**Figure 2.** Diagram of the structure of a bellows seal assembly

When the vacuum degree is tested, the flange of the CF50 blind plate is driven by a precision screw rod to cause the axial compression of the bellows, so that the ejector pin can pierce the metal packaging container. Threaded connection between top rod and top rod sleeve, and the packaging container with different height can be tested by adjusting the extension length of the ejector pin. The top part of the ejector pin is provided with a communicating hole, which ensures that the packaging container is communicated with the test chamber and releases the vacuum degree, thereby completing the vacuum degree test of the packaging container.

3. **Operational principle of integrated metal packaging container performance parameter detection device**

The measuring device for the performance parameter of the integrated metal packaging container is used as the testing object of the common metal packing container. It can realize the rapid and accurate measurement of the volume, sealing, vacuum degree and pressure strength of the metal packing container. The principle is shown in Figure 1-1.

![Figure 1-1: Schematic diagram of a test device for a wrapper container](image)

1- nitrogen cylinder; 2- pressure relief valve; 3- mass flow controller; 4- cut-off valve; 5- absolute pressure sensor; 6- screw assembly; 7- bellows seal assembly; 8- top rod; 9- differential pressure sensor; 10- precision piston; 11- test chamber; 12- horse wrapper container

**Figure 3.** Schematic diagram of a test device for a wrapper container

3.1. **Principle of volume detection**

The principle of measuring the volume of the metal packing container is as follows: by moving the precision piston to make the test chamber volume change little, the pressure change of the interlayer
before and after the variable volume is measured by the differential pressure sensor, and the volume of the interlayer is calculated according to the formula (1). The volume difference of the test chamber before and after placing the packaging container is the volume of the packaging container.

\[ V = \frac{P - (\Delta P_2 - \Delta P_1)}{\Delta P_1 - \Delta P_2} \Delta V \]  

In the formula:
\( V \)- Intercalation volume, L;
\( P \)- Initial absolute pressure of interlayer, Pa;
\( \Delta P_1 \)- Pressure difference sensor indication before volume change, Pa;
\( \Delta P_2 \)- Pressure difference sensor indication after volume change, Pa;
\( \Delta V \)- Variable volume indicator of precision piston movement, L.

3.2. Principle of Sealing Testing
The testing principle of the sealing property of the metal packing container is: placing the packing container in the test chamber, assuming that there is a hole in the packing container, then the gas in the interlayer will leak into the packing container, thereby reducing the gas pressure in the interlayer. The change of interlayer pressure in a certain time is measured, and the overall leakage rate of the packaging container is calculated according to formula (2).

\[ Q = \frac{(\Delta p_1 - \Delta p_2) V}{t} \times 10^{-3} \]  

In the formula:
\( Q \)- Overall leakage rate of packaging container, Pa·m\(^3\)/s;
\( V \)- Intercalation volume, L;
\( \Delta p_1 \)- Initial value of differential pressure sensor, Pa;
\( \Delta p_2 \)- Final value of differential pressure sensor, Pa;
\( t \)- Detection time, s.

3.3. Principle of vacuum degree detection
The test principle of vacuum degree of metal packing container is to use screw rod to move the top rod to pierce the packing container, and to measure the change of the interlayer pressure in this process by using an absolute pressure sensor. When the packaging container is damaged, the interlayer pressure will be significantly reduced. According to formula (3), the vacuum degree before the rupture of the packaging container can be calculated.

\[ p_0 = p_2 - \frac{(p_1 - p_2)V_1}{V} \]  

In the formula:
\( p_0 \)- Vacuum degree of packaging container, KPa;
\( p_1 \)- Interlayer pressure before rupture of packaging container, KPa;
\( p_2 \)- Interlayer pressure after the rupture of a packing container, KPa;
\( V_1 \)- Intercalation volume, L;
\( V \)- Volume of packaging container, L.
3.4. Principle of pressure strength testing

The test principle of the pressure strength of the metal packing container is as follows: in the test chamber, the packing container is slowly inflated by the mass flow controller to the interlayer of the test chamber, and the change of the interlayer pressure during the inflating process is measured. When the container loses stability, a sharp decrease in volume will cause a downward turning point in the pressure curve of the interlayer, and the difference value between the pressure of the sandwich and the vacuum of the packing container is the pressure strength of the container.

4. Conclusion

In view of the characteristics of metal packaging containers, an integrated device for detecting the performance parameters of metal packaging containers is designed and developed. A method of measuring the volume of metal packaging containers using micro expansion in test chamber is presented; A bellows sealing assembly was designed to intervene in the sealed test chamber so that the metal packaging container was damaged and the vacuum of the packaging container could be accurately detected; The mass flow meter is used to control the slow pressurization in the test chamber, and the pressure strength of the metal.

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