Research on the Vibration Response of Cylindrical Vessel under Explosion Shock Wave in Confined Space

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Abstract. The experimental research is carried out on the shock wave vibration response of the cylindrical explosive container under the explosion at the center point. First, a horizontal flat-head cylindrical explosion vessel was designed and the shock wave vibration test placement was carried out; secondly, the explosion shock wave vibration test in a confined space was carried out under different charges; then the vibration conditions at several typical locations were carried out Comparative measurement and analysis of its vibration frequency characteristics. The test results show that the shell vibration acceleration value at the measuring point is related to the charge amount and the distance from the explosion center; the shell vibration frequency close to the middle ring is dominated by the natural fundamental frequency, and as the shell moves away from the center to the ends, The low-frequency vibration gradually increases, and the vibration frequency component of the container head is single, and its main frequency is determined by the natural frequency of the head.

Keywords: Explosive container, internal explosion, vibration acceleration.

1. Introduction
As a special anti-explosion device, explosive container has been widely used in the fields of industry, national defense and scientific research. Its main structure includes shell, head and flange. Explosive containers will produce vibrations when they are subjected to internal explosive loads. These vibrations are not only related to their working performance, but also affect their life and strength. Therefore, exploring the laws of vibration of explosive containers will improve the design and manufacturing level and safe use of explosive containers. It has important practical significance [1,2]. The best way to analyze the vibration law of explosive containers is physical testing. Therefore, the vibration of horizontal flat-head cylindrical explosive containers under different charges is monitored [3,4], and the data is fitted to understand the vibration. The attenuation law of the acceleration value on the container structure and its relationship with the charge and the burst center distance.
2. Shock vibration experimental

2.1. Experimental design

Explosion container: The structure of the cylindrical explosion container with horizontal flat head is shown in Figure 1. The shell material is 20-gauge steel, with a length of 0.8m, an inner diameter of 0.8m, a wall thickness of 12mm, and a flat head of 20mm. The container has an axisymmetric structure, and both ends are standard flat heads, which are directly welded and connected to the shell, and 24 triangular ribs are added to the weld on the outside of the shell. In addition, due to the needs of the test, the shell is also provided with charging holes, sensor holes, observation holes and cleaning holes, and all holes are sealed with corresponding flange structures during the test.

![Figure 1. Container structure and measuring point layout](image)

The measuring point arrangement is shown in Figure 1. The measuring point A is set on the outer middle ring surface of the container, and the measuring point C is set on the same horizontal line 0.3m away from it. At the same time, measuring point D is set at the top 0.1m from the middle ring surface, and the flat head Set measuring point B in the center.

The test system is mainly composed of acceleration sensor, embedded data recorder and computer. According to previous test experience, the sampling frequency of the acceleration sensor is 250KHz, point A and C are selected as JF-100C acceleration sensor, and point B and D are selected as CA-YD-103. Before the test, all sensors must be calibrated.

The acceleration sensor is fixed on the corresponding measuring point of the container with special bolts. After being subjected to the internal explosive load, the shell surface vibrates and relies on the piezoelectric characteristics inside the sensor to generate an output charge, which is generated by the compression and expansion of the piezoelectric disc The voltage is proportional to the vibration acceleration, and is amplified and converted into a recordable voltage signal by the charge amplifier in the built-in data recorder, and then collected and stored by the data acquisition system in the recorder to obtain the corresponding acceleration signal over time. Curve.
2.2. Experimental results

The internal explosion shock vibration test was carried out twelve times, three times for 3.6g, two times for 6.8g, and four times for 5g and 10g. The charge is cylindrical passivated black gold, suspended from the charge hole, placed in the center of the container, and detonated by an electric detonator. Figure 3 to Figure 6 are the vibration acceleration waveforms of each measuring point under different doses.

![Figure 3. Vibration acceleration waveform diagram of measuring point A](image)

![Figure 4. Vibration acceleration waveform diagram of measuring point B](image)
Table 1~Table 4 list the average acceleration peak value $a$ (unit: g), burst center distance $R_w$ (unit m), proportional acceleration $aQ^{1/3}C^{-2}$ and proportional distance value $R_wQ^{-1/3}$ of each measuring point under the four kinds of doses.

**Table 1. Measured data of vibration acceleration at measuring point A**

| Serial number | Charge amount | $R_w$ | $a$  | $aQ^{1/3}C^{-2}$ | $R_wQ^{-1/3}$ |
|---------------|---------------|-------|------|-----------------|----------------|
| 1             | 3.6 g         |       | 545.2| 0.00723         | 2.68           |
| 2             | 5 g           | 0.41  | 563.7| 0.00834         | 2.40           |
| 3             | 6.8 g         |       | 610.8| 0.0100          | 2.16           |
| 4             | 10 g          |       | 684.1| 0.0127          | 1.90           |

**Table 2. Measured data of vibration acceleration at measuring point B**

| Serial number | Charge amount | $R_w$ | $a$  | $aQ^{1/3}C^{-2}$ | $R_wQ^{-1/3}$ |
|---------------|---------------|-------|------|-----------------|----------------|
| 1             | 3.6 g         |       | 551.4| 0.00731         | 2.61           |
| 2             | 5 g           | 0.4   | 592.7| 0.00877         | 2.34           |
| 3             | 6.8 g         |       | 684.3| 0.0112          | 2.11           |
| 4             | 10 g          |       | 825.0| 0.0154          | 1.86           |
Table 3. Measured data of vibration acceleration at measuring point C

| Serial number | Charge amount | $R_w$ | $a$   | $aQ^{1/3}C^{-2}$ | $R_wQ^{-1/3}$ |
|---------------|---------------|-------|-------|------------------|---------------|
| 1             | 3.6 g         |       | 150.3 | 0.00199          | 2.92          |
| 2             | 5 g           | 0.447 | 167.3 | 0.00247          | 2.61          |
| 3             | 6.8 g         |       | 220.2 | 0.00361          | 2.36          |
| 4             | 10 g          |       | 292.8 | 0.00546          | 2.07          |

Table 4. Measured data of vibration acceleration at measuring point D

| Serial number | Charge amount | $R_w$ | $a$   | $aQ^{1/3}C^{-2}$ | $R_wQ^{-1/3}$ |
|---------------|---------------|-------|-------|------------------|---------------|
| 1             | 3.6 g         |       | 289.8 | 0.00384          | 2.74          |
| 2             | 5 g           | 0.42  | 351.5 | 0.00520          | 2.46          |
| 3             | 6.8 g         |       | 431.8 | 0.00707          | 2.22          |
| 4             | 10 g          |       | 483.1 | 0.00900          | 1.95          |

3. Experiment analysis

In the test, the acceleration peak value of the same measuring point under the same amount of charge is also different, mainly due to the slight difference in the charge amount and the deviation of the charge position each time, which will cause uneven load distribution and lead to differences in vibration acceleration.

From the data in the table, we can see that the peak acceleration will increase with the increase of the test dose (or the decrease of the burst center distance), but this increase is not linear. What kind of relationship exists between them? Can they be established? The corresponding calculation relationship will be discussed in the next section of this article.

Vibration acceleration signal is a non-cyclic stationary signal, we choose FFT algorithm for power spectrum analysis. Figures 7 to 10 show the frequency spectrum of acceleration waveforms at various measuring points under different doses.

Figure 7. Vibration acceleration frequency spectrum of measuring point A
It can be seen from the various spectrograms that the increase in charge does not seem to have an obvious dependence on the vibration frequency, which may be determined by the mechanical characteristics of the structure itself. Within the scope of the test dose, the main frequency of the shell vibration of the middle torus is concentrated near the natural fundamental frequency (theoretical value $f = 1462 \text{Hz}$). For example, the spectrogram of measuring point A shows that the vibration energy is mainly concentrated here.

From the spectrograms of measurement points C and D, it can be seen that with the increase of the burst center distance, a lot of low-frequency components appear in the vibration, while the frequency near the fundamental frequency gradually decreases, indicating that the farther from the middle ring
surface, the lower frequency is non-axisymmetric. The easier the bending vibration is to be excited, the main reason is that the cylindrical shell is not completely symmetrical, such as the sensor hole, charge hole and the support of the support to the bottom of the shell and the eccentricity of the explosive position on the shell. It can cause asymmetric response. In addition, the closer the two ends of the shell, the gradual increase of the boundary effect is also one of the reasons.

For the vibration frequency at the container head, it can be seen from the spectrogram of measuring point B that its frequency component is single, which is mainly determined by the natural frequency of the flat head, and is not greatly affected by the natural frequency of the cylindrical shell.

4. Conclusion
Through the above discussion and analysis, we can get the following insights:

1) The shell vibration acceleration value is related to the charge amount and the burst center distance, and increases with the increase of the charge amount (or the burst center distance decreases). The calculation formula can be obtained by regression analysis of the test data.

2) The vibration frequency of the shell near the middle ring is dominated by the natural fundamental frequency, and as the shell moves away from the center to the ends, the low-frequency vibration gradually increases, while the frequency near the fundamental frequency gradually decreases, indicating that the farther away from the middle ring, Non-axisymmetric bending vibration is more easily excited. The vibration frequency component of the container head is single, and the main frequency is determined by the natural frequency of the flat head, and is not greatly affected by the natural frequency of the cylindrical shell.

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