Fragment Velocity Test System Based on PVDF

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Abstract. In order to solve the problem of low measurement accuracy, large environmental interference and high cost of production in fragment velocity test, this paper proposed the fragment velocity test system by using PVDF piezoelectric film, NI-PXI platform and LabVIEW graphical programming language. The test system mainly includes PVDF film, adjusting circuit, acquisition module and terminal control software. The adjusting circuit amplifies the weak signal of the PVDF sensor. The acquisition module is responsible for reading the data collected by the data acquisition card for subsequent analysis and storage. The terminal control software executes data multi-channel acquisition, storage and display. The test system is stable and reliable with high accuracy through experimental verification.

Keyword. PVDF Film, Fragment Velocity, LabVIEW, PXI Platform

1. Introduction

Fragment velocity is one of the important indicators to measure the degree of damage. As the basic information to improve the capability of destruction, the technology of fragment velocity measurement plays a vital role in the development of destructive weapons. However, the current fragment measurement method still has many problems such as cumbersome testing process, low test accuracy, and poor repeatability.

At present, many people at home and abroad research on the fragment velocity test system, for example, Xu established fragment velocity test platform which combining laser vertical target and film switch array. Also, designed a signal processing circuit of thin film switching array and propose a CPLD pulse width coding algorithm for multi-channel signals. Tian presented the construction method with a circular screen of light screen velocity measuring device, the circular ring light source and received array placed at the same center of circular are designed to form two cylindrical detection light screens with equal intervals to measure accurately the velocity of fragments which flying in any direction. Zhang proposed band-pass filtering properties and multi-resolution analysis based on discrete wavelet transform, combined wavelet threshold de-noising method for wavelet filtering of fragmented over-target signals. Liu proposed a fragment velocity method based on photogrammetry technology. By analyzing the sequence of projectile motion images captured by high-speed cameras, they restored the equation of motion of the projectile and obtained the flight velocity of the projectile. The effective measuring area of WTS03 light curtain target developed by Czech Prototypa Company was 950mm×950mm, and the velocity of the projectile can be measured in the range of 50-3000m/s. The accuracy of the measuring velocity reaches 0.2%. The Skyscreen III light curtain target produced by USA Oehler Company was mainly used for the velocity measurement of bullets.
measured an effective area of 84 square inches and could measure speeds of 1000-4000 feet per second.

This study designed a fragment velocity test system based on PVDF film\textsuperscript{10-11}. The signal collected by PVDF sensor firstly is processed by an adjusting circuit. Secondly the processed signal is collected by PXI platform. Lastly, we achieve multi-channel acquisition, storage and display of data finally through terminal control software.

2. Overall Design

Test equipment includes PVDF piezoelectric film, guide rail, support structure, signal adjusting circuit, PXI platform and skyscreens. It comprises a total of two piezoelectric films placed front and back, and the PVDF piezoelectric film is divided into several piezoelectric measuring units. The PVDF film is fixed on the guide by the support structure, and the distance between the two films can be adjusted by the guide. The system records penetration time and penetration point when the fragment penetrates the front and back PVDF films respectively. Using the time it takes to fly through the two PVDF piezoelectric films, the fragment velocity can be analyzed and calculated. The actual velocity is measured by skyscreens. The sub-region PVDF film can effectively solve the short circuit problem compared with other single films which using to velocity measurement. The main device is shown in Figure 1 below.

![Figure 1. Fragment velocity measuring device.](image)

3. Hardware System Design

The hardware mainly extracts and regulates the signal and transmits it to the host computer, mainly including signal adjusting circuit and PXI platform deploy.

3.1. Signal Adjusting Circuit

PVDF film output impedance can generally reach $10^{13} \Omega$, it can equivalent to a charge source under the influence of external force, and the output signal is charge. Therefore, the input impedance of the preamplifier needs to be high and the noise is low. After consulting, we choose TI's LF356 operational amplifier as the core device.

The first stage is a charge amplifier in the preamplifier circuit. Its important role is converting the charge signal into a voltage signal, amplifying the weak signal produced by the piezoelectric sensor, converting the high output impedance of the voltage signal to low output impedance, and improving the load capacity of the circuit. The second stage is a low pass filter, and it is used to reduce high frequency noise. Signal adjusting circuit design is shown in Figure 2.

![Figure 2. Signal adjusting circuit.](image)
3.2. PXI Platform Deploy

Hardware selection is shown in Table 1:

| Name              | Quantity | Description                                                   |
|-------------------|----------|---------------------------------------------------------------|
| PMA 1115          | 1        | Windows 7, 15-inch LCD touch screen display with 1024 * 768 resolution |
| PXIe 1082 Chassis | 1        | 8 slots, maximum bandwidth8GB/s, VCVO on board clock         |
| PXIe 6853 Capture Card | 2    | Multi-function DAQ, 16AI, 1.25MS/s, 4AO, 48DIO, 4CTR          |
| PXIe 8880 Controller | 1  | Intel Xeon 8 Core, 2.3 GHz                                   |
| SCB-68A Quick-Reference Label | 4    | 68-pin shielded junction box                                 |

4. Software System Design

The software part is developed by LabVIEW graphical programming language. According to the requirement of the test system, we realize multi-channel data acquisition, storage and display in our test system.

4.1. GUI

The graphics user interface of the system is shown in Figure 4, which includes the acquisition board channel deployment, trigger setting and real-time waveforms display. The specific operation process is to set the related parameters of the signal acquisition card. After triggering, the system starts real-time multi-channel acquisition and stores the collected data in a binary file format to the computer hard disk.

![Figure 3. Operation interface diagram.](image)

4.2. Program Design

When the fragment penetrates the PVDF film, a weak charge signal is generated. The signal is processed by the signal adjusting circuit, and transmitted to the acquisition card. Finally, the program realizes multi-channel data acquisition, storage and display.

- Acquisition module: In this process, we set the channel parameters, trigger settings, sampling clock settings, read function. This system selects multi-channel analog signal input and sets the input voltage range to ±10V. The trigger mode is triggered by the rising edge of the digital
signal, the sampling rate is 1MB/S, and the read function category is analog multi-channel multi-sampling 2D DBL. As shown in Figure 4.

**Figure 4.** Acquisition module.

- Storage and display module: we store the data as a binary file (.tdms). In this process, we set the storage path, storage format and the read file storage path to achieve data playback and real-time waveform display. As shown in Figure 5.

**Figure 5.** Storage and display module.

5. Analysis of Test Results

The system is tested in real experiments. Figure 6 is an amplified view of the signal front-end pulse collected in a single test. It can be clearly seen from the figure that the time when the fragments penetrate the PVDF film on the front and back sides respectively. The velocity of the fragment can be calculated according to the time difference between the front and back moments.

**Figure 6.** Single test result.

When testing the performance of the test system, ten routine tests are conducted. After each test, if the film’s damaged area exceeds 60% of the whole film or the film is short circuit, we will replace it. The results are showed in Table 2. In the data processing, we use 20% of the maximum value of the filtered signal pulse as the time when the fragment penetrate the PVDF. Then we calculate the time
The velocity is the ratio of the distance between the membranes and the time of flight. According to the final results, the average error is 1.28%, meeting the test requirement.

| Test Times | Test Value (m/s) | Actual Value (m/s) |
|------------|-----------------|-------------------|
| 1          | 722             | 737.3             |
| 2          | 724.2           | 734.4             |
| 3          | 720.5           | 731.9             |
| 4          | 729.1           | 734.4             |
| 5          | 733.7           | 735.5             |
| 6          | 732.7           | 734.6             |
| 7          | 726.7           | 734.2             |
| 8          | 723.7           | 737.3             |
| 9          | 725.1           | 735.1             |
| 10         | 715.1           | 732               |
| Average Value | 725.3         | 734.7             |
| Standard Deviation | 5.61         | 1.93              |

6. Conclusion

In this paper, a fragment velocity test system is proposed. This system uses PVDF film as sensor, and is designed on the PXI platform. This system mainly includes PVDF piezoelectric film, guide rail, support structure, signal conditioning circuit, PXI platform. It realizes the integration of signal acquisition, calculation processing, display and storage, and improves the system's anti-interference, compatibility and scalability. Through experimental tests, all functional modules run normally. The system can accurately determine the parameters and performance indicators of the fragments. Compared with the traditional fragment velocity test methods, our system has the advantages of simple operation, friendly man-machine interface and high measurement accuracy.

7. References

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