Design of low-power and changeable-frequency underwater data acquisition system

Yang Zhuojing[1,a], Zhang Jianwei[1,b], Jiang Fan[1,c],Hao Wenjie[1.d]

[1]Centre for Hydrogeology and Environmental Geology Survey of China Geological Survey，

Key Laboratory of Monitoring Technology of Geological Environment，MLR

[a]yangzhuojing@chegs.cn, [b]zhangjianwei@chegs.cn, [c]jiangfan@chegs.cn, [d]haowenjie@chegs.cn

Keywords: underwater explosions; blast shock wave; pressure; measurement

Abstract. The conception and characteristics of underwater blast shock wave and gas bubble pulsation theory are explained in this paper, based on which， the measuring principle and sampling parameters of the overpressure measuring system of underwater blast shock wave are figured out. The underwater blast pressure sensor,A/D converter, trigger control circuit, communication interface circuit , battery and other circuits are packaged in an airtight, water-proof and solid steel shell, which make up of a underwater blast shock wave measuring system working independently. This system has advantages of small size, low power consumption , high sampling frequency, anti-interference and no-need of cable, and is fit for large-scale multi-point measurement in underwater.

1. Introduction

The study of underwater explosion has a long history. Early research is mainly for military applications. Researchers in various countries take the spherical charge explosion shock wave in the water as the main research object. They studied the law how the shock wave is formed, spread and attenuation, and they set up a set of theoretical and computational formulas. With the world economic recovery after World War II, the underwater explosion is widely used in civil construction. Such as port construction, dredging the river and exploration of underwater earthquake all need the underwater explosion theory. The theory has great economic and social benefits in many aspects. In modern blasting, underwater blasting holds a certain position, and the application is becoming wider and wider. However, underwater blasting is mostly related to the safety of buildings, so it is usually required for field monitoring.

2. Theoretical research of shock wave occurred in the underwater explosion

Detonation products of high temperature and high pressure emerge as the times require under such conditions that volume do not change when the explosive instantaneous explosion in the water, and explosive energy change into internal energy of the detonation product. Based on the reason of detonation product expand as very high speed, water medium forming water shock wave and this process consumes a portion of the energy. This part of energy accounts for about 53% of the total energy. The other portion of the energy that is produced detonation stay inside the detonation products and expand outward in the form of bubbles. This behavior promote the water radial flow.This part of energy accounts for about 47% of the total energy.

The pressure inside the bubble decreases with the Bubble expansion. Due to the inertia of water, bubble would expand to the maximum and the pressure inside the bubble is less than the pressure of the surrounding seawater when the pressure drops to the static pressure of the surrounding water medium.At this time, the lined up water takes reverse movement. It is potential compressed air bubble from the surrounding to the center. Also due to the inertia of sea water, the bubble is compressed to a very small extent, and it is internal pressure greatly exceeds the static pressure of the surrounding sea water. Similar characteristics of the same bubble and the explosion occurred, and pressure pulsation produce in the surrounding again. It is called Second-order Wave. Mass produced in the explosion continues to do circular motion such as expansion, compression, expansion and compression up to ten times. This movement is called bubble pulsation.

The second wave pressure wave has a destructive effect on the target. It's not practical to have a number of inflation pressures. The maximum pressure of Second-order Wave is about 10~20% of the shock wave pressure. Continued time greatly exceeds the time of shock wave pressure. Damage increased significantly when bubbles dilate on the second time around the target. Therefore, the energy of the explosive explosion can be considered as the sum of the bubble energy which can be used to the first pulsation of the bubble.

The waveform of underwater explosion is shown in Figure 1. Underwater explosion signal is a single transient signal which is Similar to the single exponential decay (shock wave) signal and cosine pulse (Second-order Wave). That is to say it is transient, finite length in the time domain and it only appears in the explosion of a moment. But the spectrum is wide. The range can be reached 0.1HZ -1KHZ. The front of the shock wave is steep and peak value is sharp. Compared to the shock wave, the two wave peak is gentler, and the duration is longer. There is a long interval between the shock wave and the Second-order Wave and no ups and downs in the middle.

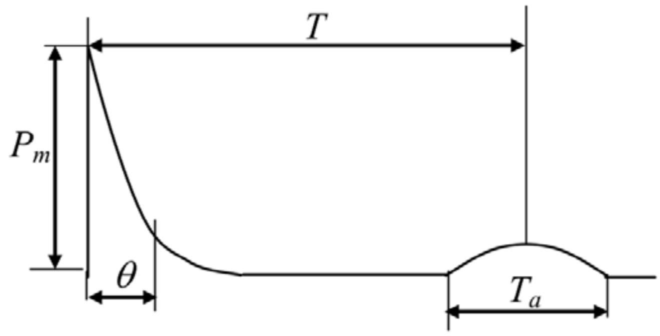

Figure 1.The waveform of underwater explosion

Pm: Peak value of explosive shock wave

θ: Exponential decay time constant of explosion shock wave, $\theta \leq 2$ms

Ta: The duration of the second-order wave, tens of milliseconds to a few hundred milliseconds

T: The shock wave and the second-order wave of the time interval, Tens of milliseconds to a few seconds

3. Design of test system

Underwater explosion shock wave data recorder is made up of three parts, which are data recorder, interface, and test data processing software. Data recorder is a miniature test device that sets pressure sensor, Transient Waveform Recorder, USB interface, power supply as a whole. It built in voltage amplifier and DC power supply. The input signal is amplified and converted to digital signal to realize automatic digital storage.

According to the characteristics of underwater shock wave signal and bubble pulse signal, the sampling process is divided into high speed sampling and low speed sampling. The high speed sampling frequency is 2MHz, the memory capacity is 1088kW, the low speed sampling frequency is 200 kHz, the memory capacity is 960kW, and the resolution is 14byte all. Both internal and external trigger are used in Trigger scheme. Trigger scheme based on negative delay theory. This scheme can realize real-time data acquisition, quantification and storage and waveform drawing. The reading interface adopts the technology of object oriented design. PC is used as a hardware platform and Windows is used as a software platform. Program design by VB. The software has the function of data processing, such as conventional waveform display, print and calculation. The staff can automatically analyze and process the data recorded by the computer through the USB interface after data collection.

Sensor is the core of testing technology. 138A38 series ICP pressure sensor produced by PCB is applied to the system. The series sensor is specially used for underwater explosion test. Technical indicators are as follows:

(1)Pressure range: 0.07~344740kPa;

(2)Output voltage range: -5~+5V;

(3)Sensitivity: 3.748mV/MPa;

(4)Maximum bearing pressure: 344750kPa;

(5)Resonance frequency: ≥1000kHz;

(6)Rise time: ≤3μs;

(7)Low frequency limit cut-off frequency: ≤2.5Hz;

(8)Nonlinearity≤2.0%;

(9)Supply voltage range: 20~30VDC;

(10)DC bias voltage range: 8~14VDC.

The sensor has the advantages of small size, fast response and high accuracy. But it needs constant current source power supply, and it has DC bias voltage. So it is necessary to provide the sensor with the signal conversion circuit and the conditioning circuit. The purpose is to adjust the shock wave signal to a suitable voltage range, which is convenient for the further processing of the signal. The trigger scheme of the data recorder is based on external trigger and negative delay: The negative delay scheme is used when the signal amplitude is greater than the set of the trigger, and the system is in the state of circular collection when the signal amplitude is less than this value. This method can effectively prevent false triggering and it is able to record the whole shock wave accurately and completely.

4. System calibration and calibration

Sinusoidal or square wave signal is used as the input signal of the circuit that output of signal generator. The waveform of underwater explosion signal is displayed on the software interface. So a series of bit values are obtained, and the sensitivity of the pressure channel is fitted by the least square method.

The hammer is a device similar to a pressure generator can produce half sine pulse pressure. There is a piston at the top of the closed high pressure cylinder. Pressure sensor is installed on the outer side of the high pressure oil chamber. Hammer gaining some momentum when the hammer fall free, and it impacts piston. Piston compresses liquid in the high pressure cylinder, and so pressure generate in cylinder. The hammer and the piston reached the maximum stroke and stress in the cylinder reached maximum when all the kinetic energy is converted into elastic potential energy. Then the liquid will push back to the piston and drop hammer until the drop jump off the piston, cylinder pressure back to zero. 1.5 sinusoidal pressure pulses will be generated in the cylinder once hammer dropping strike piston. The peak pressure and the pulse width can be changed by adjusting the falling mass and height. Drop hammer dynamic calibration system is shown in Figure 4. It is composed of a drop hammer device, sensor, standard test system, calibrated charge amplifier, high speed digital acquisition card.

When the heavy hammer falling produce a pressure, the pressure value is detected by 3 standard sensors and the pressure signal is transmitted to the soft interface by the charge amplifier for data processing, and then an average value is obtained as the true value of the peak value of the pressure signal; At the same time, the ICP pressure sensor put the pressure signal into the test circuit to collect, store and display the signal. Finally, through the comparison of these two values, the sensitivity coefficient and error of the test system pressure channel are obtained. This result is used to calibrate the sensitivity coefficient.

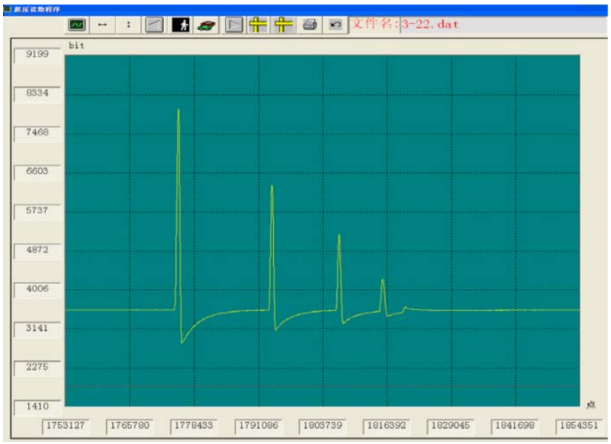

Figure 2 a curve with a hammer

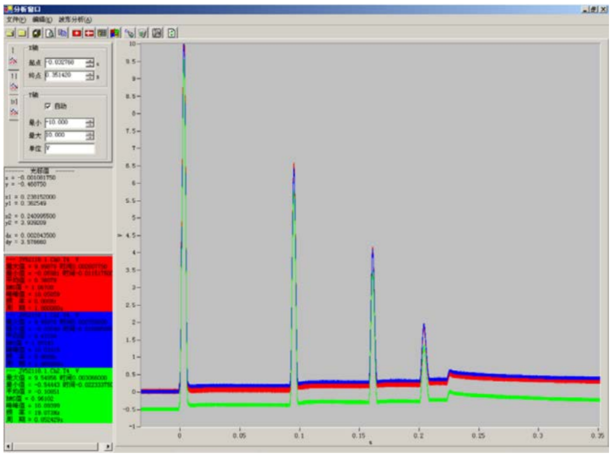

Figure 3 the pressure curve diagram of acquisition value of standard pressure sensor.

Figure 2 is a curve with a hammer,Figure 3 is the pressure curve diagram of acquisition value of standard pressure sensor. Ion test conclusion show that linear error of the calibration sensitivity and sensitivity of the system is relatively large. The average value of the sensitivity can be used as the true value of the system sensitivity after multiple calibrations. Calibration sensitivity: 0.2195 MPa/bit

5. Conclusion

The system has characteristics such as micro power consumption, high sampling frequency, delay time and trigger level programming can be adjusted. The obvious advantages of the system are strong anti-interference and no cable lead. This system is especially suitable for large scale and multi - point test. Because of these advantages and characteristics, the system greatly improved the international competitiveness of the instrument, and it provides reliable technical support for the research of underwater explosion pressure. This system has a broad market prospect.

Acknowledgments

This paper was supported by the project “research and demonstration of landslide monitoring technology”, the project encoding was “1212011220165”.

References

[1]Zamyshlyayev B V. Dynamic Loads in Underwater Explosions[Z]，AD-757183，1973.86-120.

[2]Gong S W. Structural analysis of a submarine pipelinesubjected to underwater shock. International Journalof Pressure Vessel and Piping, 77(2000): 417~423.

[3]Liu Jian - hu .A simplified method for analyzing theresponse of GRP ship to underwater explosion.Jounalof Ship Mechanics, Jun. 2000

[4]Gong S W. Transient response of floating compositeship section subjected to underwater shock . CompositeStructures, 46(1999): 65~71.

[5]Gong S W . Transient response of Stiffened CompositeSubmersible Hull Subjected To Underwater ExplosiveShock . Composite Structure , 41(1998)

[6]Cho-Chung Lian. Study of the nonlinear responses of asubmersible pressure hull . International Journal ofPressure Vessels and Piping, 75(1998): 131~149.