Research on Multi-Physical Field Parameters Measurement System of Hydraulic Pipeline Based on LabVIEW

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Abstract: The test system of multi-physical field parameters testing system for hydraulic pipeline is built based on NI platform. The system includes hardware platform based on NI PXIe and software system on account of LabVIEW. According to the test requirement of multi-physical field parameters, the hardware platform of the multi physical field testing system includes the collection box, data acquisition card and acceleration, pressure, strain, flow rate, temperature sensor. A software system based on LabVIEW has been developed, including data acquisition and real-time data playback two parts, real-time data acquisition includes on the five physical parameters acquisition and real time display, which mainly describes vibration three physical quantity, acceleration, stress, strain spectrum real-time display and peak of the frequency spectrum display and 3D waterfall diagram of real-time rendering. The pipeline experiment system was set up, and the experimental test was carried out under the condition of hydraulic pump sweeping frequency, constant frequency and constant pressure, which verified the multi-physical field parameters test system developed in this paper.

Keywords: Multi-physics field; LabVIEW; 3D spectra; Pipeline testing

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1 Introduction

Hydraulic transmission and other piping systems are widely used, but due to the aging corrosion of the pipeline's own materials, the damage of the pipeline structure, the discontinuity of the pipeline interface, mechanical vibration, etc. The pipeline system is difficult to avoid failure [1-3]. At present, the simulation method is adopted to design the hydraulic pipeline, but the simulation effect is difficult to describe its working state. Due to the difficulty during processing the inner wall of the pipeline and the complicated process, the internal defects are often difficult to be discovered, and the flow of the liquid in the pipeline is very complicated, which makes it difficult to theoretically calculate the pipeline. Furthermore, it is not easy to guide the use of hydraulic pipelines [4-7]. Therefore, for the pipeline system, more experiments are needed to detect the working condition, and it should be monitored real time while it works. There is few experiments for the test system for the hydraulic pipe. The test system of the pipeline system will bring significant economic and environmental benefits [8-12].

The multi-physics test system for pipeline systems is researched in this paper. First, according to the test requirement of multi-physical field parameters, the hardware platform of the multi-physical field testing system includes the collection box, data acquisition card and acceleration, pressure, strain, flow rate, temperature sensor. Finally, the multi-physical parameter system experiment of the pipeline system was carried out, the frequency sweep experiment and the experiment of changing the pressure and rotation speed were carried out to observe the operation of the system.

2 Hardware

The multi-physical parameter test system for hydraulic pipelines includes hardware and software. The hardware system includes sensors, data acquisition cards, chassis, and control computers. The multi-physical parameters are measured by the sensors including acceleration, strain, pressure, flow, temperature. After anti-aliasing filtering, AD conversion, the information is fed back to the acquisition card. Finally the data is transformed into computer processed by the LabVIEW software. The five parameters are measured by the multi-parameter test system of hydraulic pipeline including 16 acceleration channels, 8 stress channels and 16mixed parameters of temperature, pressure, and flow channels. The sampling frequency ranges from 20 to 3000 Hz.

Figure 1 shows the overall structure of the hardware system. The acceleration is measured by PXIe-4499, stress is measured by PXIe-4330 and the pressure, flow and temperature are measured by PXIe-4302.

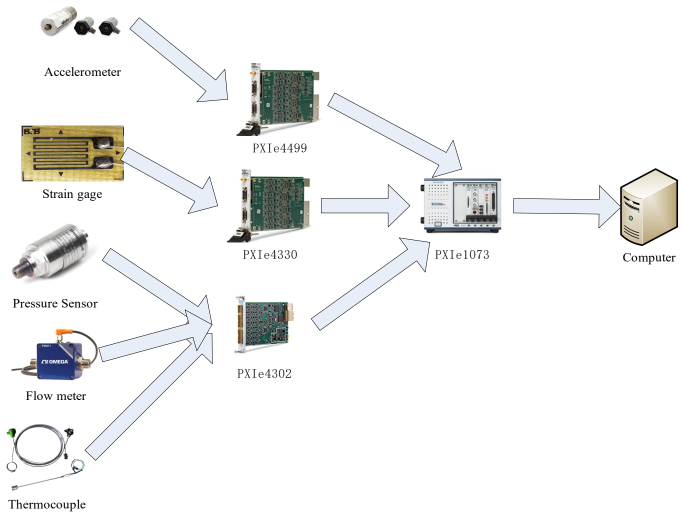

Fig.1. Hardware connection diagram

3 System design

The test system of software part is divided into four parts as data acquisition, data processing, data storage and data playback. Data acquisition part includes acceleration acquisition, strain acquisition, pressure acquisition, temperature acquisition and flow acquisition. The data processing display part includes real-time display of its time domain information, frequency domain information and 3D waterfall plots during the acquisition process. Data saving modular saves the current measuring data into the specified path of lvm file format.

Data playback modular can play back the lvm data with the rhythm of step by step or in any step length. The data can be intercepted and analyzed with band-stop filter, then all frequency components can be filtered with Power spectrum method.

3.1 Front panel design

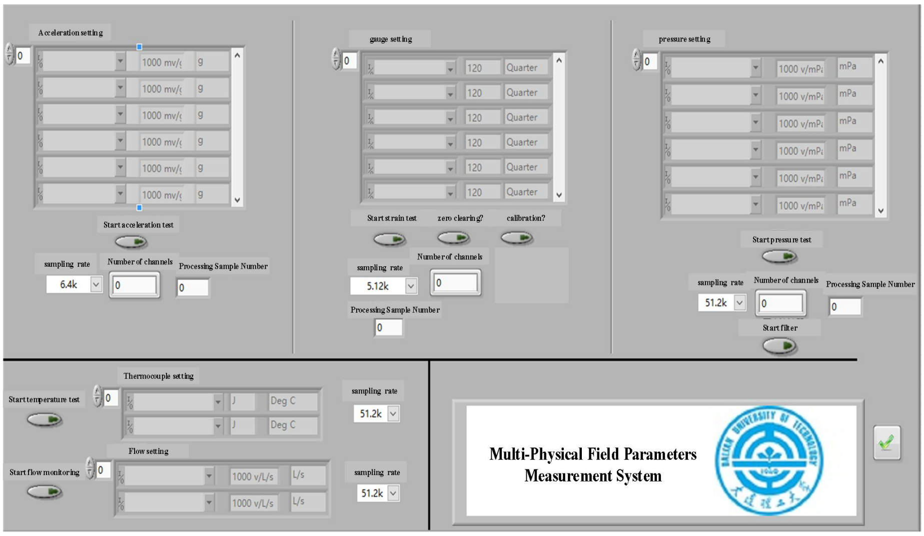

Fig.2. Setting interface of multi-physical parameters of pipeline

The setting interface is shown as Figure 2 containing five physical parameters settings, where the acceleration panel is locating at left upper region including the acceleration channel selection, sensitivity selection and unit selection. Acceleration open button is put in the low part of the panel where the acceleration test, sampling rate and channel number can be set. The selection of the acceleration channel is a pull-down list. The list includes all the channel information connected to the computer and the virtual channel. The sensitivity unit is mv/g. The value can be input directly as the scroll wheel being used to adjust the setting value.

The real-time acquisition interface is shown as Figure 3. The right column is the control box which 5 kinds of data can be measured. Each key under the control box can be set as saving, setting, starting, pausing and stopping. The measurement data is recorded to the appointment file when clicking the save key as clicking again to end the writing process. Next experiment is inspired when changing the filename as jumping to the setting panel. Four windows are provided to observe all the measuring physical parameters. Each window can be selected as the observed physical parameter and channel. Time domain, frequency domain and 3D waterfall plot can be easily changed to research the detail of the measured physical parameter.

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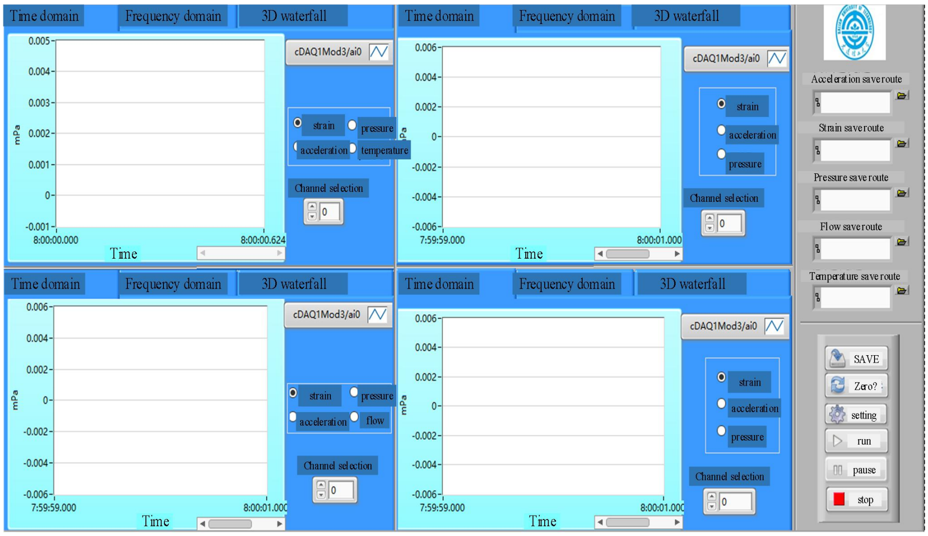


Fig.3. Acquisition interface

3.2 Software design

Five kinds of the multi-physics parameter data acquisition system of the hydraulic pipeline could be measured at the same time. The parallel structure is adopted as the simultaneous acquisition and simultaneous processing function of the software are more efficient, although there may be microsecond delay during display course. The acceleration acquisition calculation program is shown as Figure 4. The strain acquisition block diagram is shown as Figure 5, and the data processing module is shown as Figure 6.

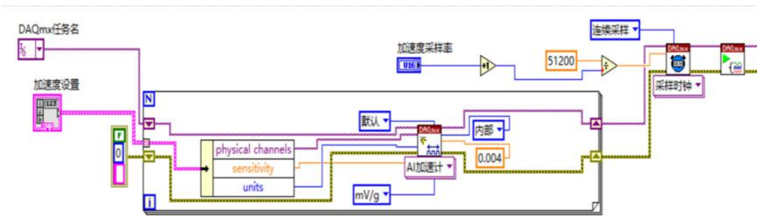


Fig.4. Acceleration acquisition block diagram

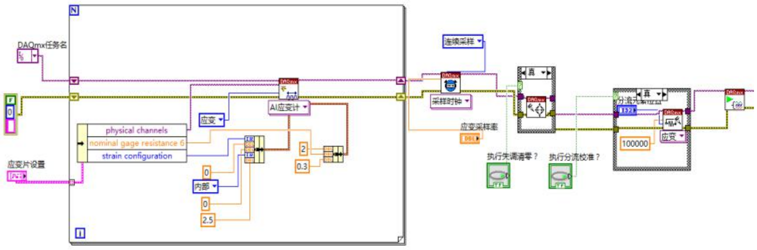


Fig.5. strain acquisition block diagram

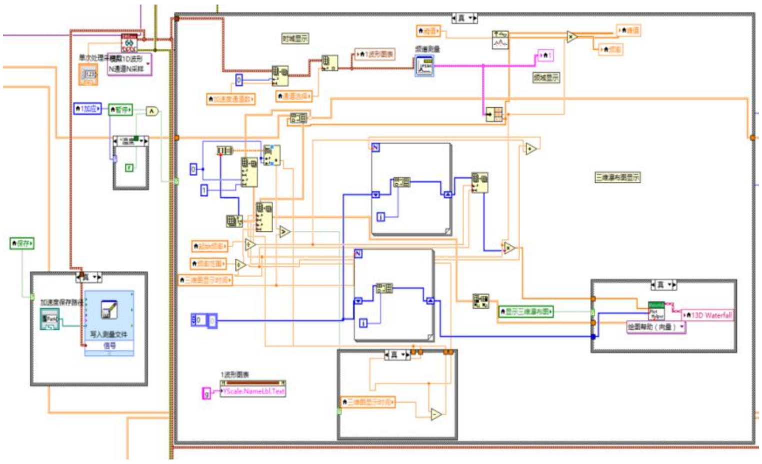


Fig.6. data processing block diagram

4 Experiments

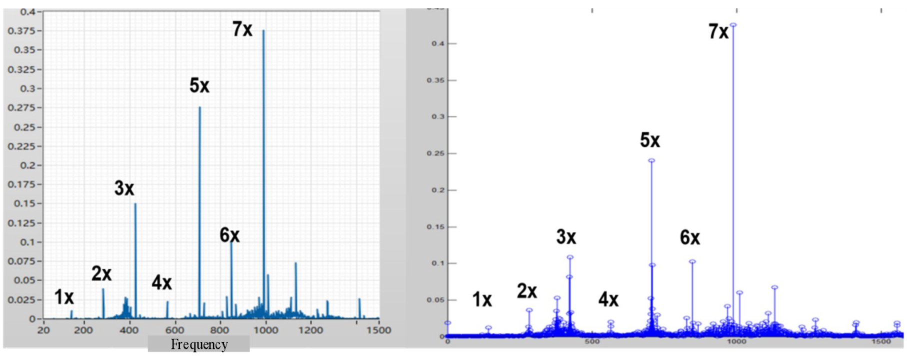
The overall layout of the hydraulic pipeline system test bench is shown as Figure 7. The multi-physical parameters of the hydraulic pipeline are measured by the sensors connected to the pipeline. The speed of the pump is driven by the frequency converter as pressure controlled by the throttle valve, and the pump output oil passes through the pipeline which the vibration are produced. The pipeline is a straight pipe. This pipeline is straight. Two pressure sensors are adopted to measure the inlet and outlet pressures respectively. Two acceleration sensors are used to measure the vibration of the pipeline in both the x and y directions. The strain gauge is attached to the pipe to measure the strain at that point. The specific sensor configuration is as follows. Acceleration sensor of channel 0 is used to measure the radial vibration of the pipeline. Acceleration sensor of channel 1 is used to measure the axial vibration of the pipeline. The strain of the pipeline is measured by the strain gauge of channel 1. The inlet pressure is measured by the pressure sensor of channel 0. The outlet pressure is measured by the pressure sensor of channel 1.

Fig.7. Overall diagram of the pipeline test bench

4.1 Experiment of test system under different conditions

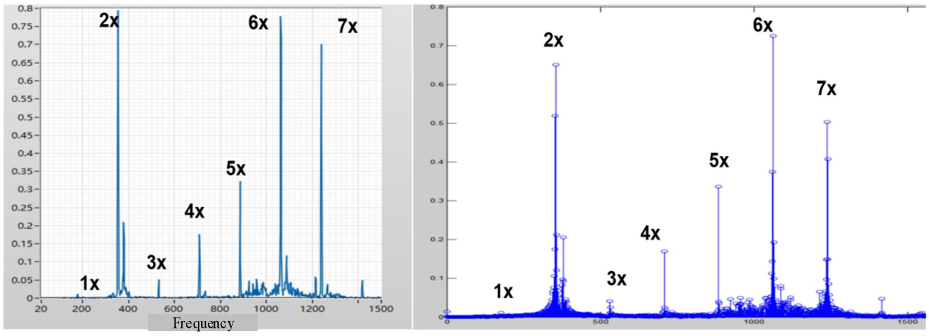
By adjusting the throttle valve, the outlet pressure of the pipeline is limited to 4 MPa, the vibration signals of the pipeline at different speeds (1200r/min, 1500r/min, 1800r/min) is measured. The frequency domain of the vibration signals of the pipeline under different working conditions is analyzed. The Matlab program is used to compare the processed data and verify the data acquisition system.

It can be seen that the frequency error of the acceleration response is little as changing the speed under the pressure of 4 Mpa. Compared with the Matlab program, there is certain error when frequency analysis since the fft algorithm is different.



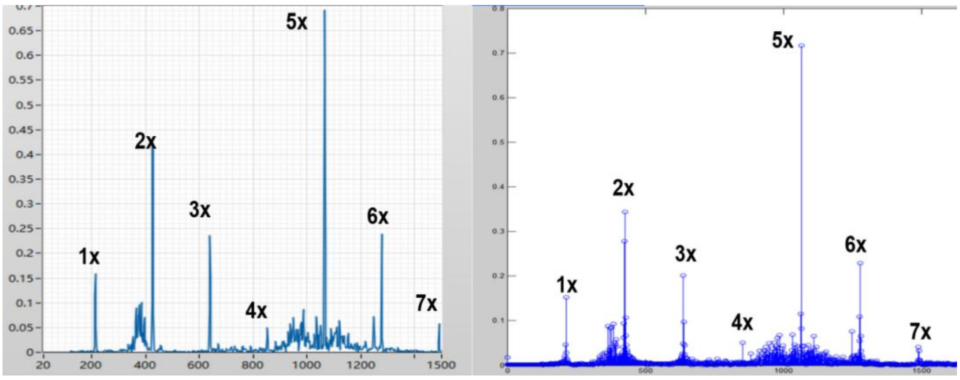
(a) Acceleration fft diagram at 1200r/min (b) Matlab processing

Fig.8. Lateral acceleration response at 1200 r/min



(a) Acceleration fft diagram at 1500r/min (b) Matlab processing

Fig.9. Lateral acceleration response at 1500 r/min



(a) Acceleration fft diagram at 1800r/min (b) Matlab processing

Fig.10. Lateral acceleration response at 1800 r/min

4.2 Experimental of pipeline natural frequency test

The test system is installed in the hydraulic pipeline. Through changing the speed of the plunger pump from 0 to 1800r/min, the time domain information of acceleration, strain and pressure and the waterfall map information could be observed. Through data playback, resonance point and its corresponding natural frequency are found out as observing the time domain of the whole process of sweeping and three-dimensional waterfall map information. The measurement effect is shown as Figure 11. The upper left is the three-dimensional waterfall diagram of the acceleration as sweeping. It can be clearly seen that the amplitude of each frequency changing as time going on.

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When the vibration frequency excited by the motor speed gradually approaches the natural frequency of the pipeline, the pipeline shows strong vibration which can be seen from the variance of the three-dimensional waterfall map. The upper right is spectrum diagram of the vibration signals, which is the real-time spectrum of the data set. It can be seen that the peak is corresponding to that of the three-dimensional waterfall map. It can be seen the vibration has just passed through the resonance state, through the three-dimensional waterfall map of the strain at the bottom left,.

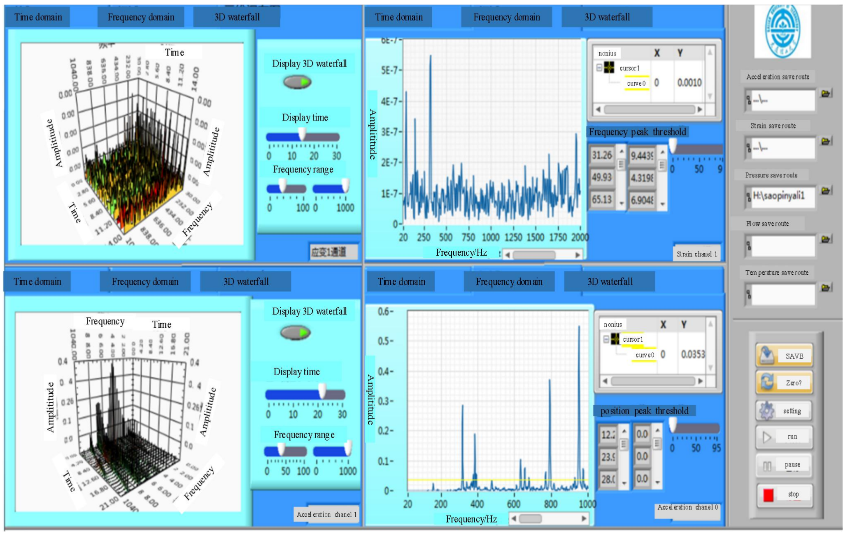

Fig.11. Graph of sweeping frequency of measurement effect

The frequency corresponding to its resonance point is found by its three-dimensional waterfall map, as shown in Figure 12. Through the three-dimensional waterfall of the acceleration signals, the first-order and second-order resonance point frequencies are 377.2 Hz and 1082.0 Hz, respectively. It can be seen the natural frequency is similar with which measured by the hammer method.

Through the three-dimensional waterfall of the strain, the first-order and second-order resonance point frequencies are 377.8 Hz and 1083.4 Hz, respectively. It can be seen the natural frequency is similar with which measured by the hammer method and acceleration method. The natural frequency of the pipeline can be obtained by sweeping experiments. The difference between this value and the theoretical value is small. The strain and acceleration are consistent with the sweep frequency experiment setting. The system performs well in the frequency sweeping experiment.

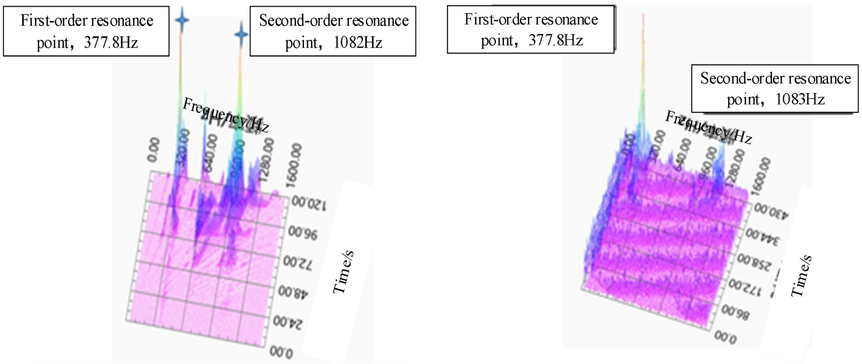

Fig.12. Three-dimensional waterfall diagram of radial acceleration sweeping process

4.3 Measurements of hydraulic pipelines under different pressures

By changing the frequency converter, the speed of the plunger pump is stabilized at 1800r/min, the vibration response test of the pipeline under different fluid pressures (4MPa, 5MPa, 6MPa) is measured by adjusting the opening of the throttle valve. The multi-physical parameters of the hydraulic pipeline test system is used to analyze the vibration response under different working conditions of the pipeline.

Adjusting the speed to 1800r/min and changing the pressure to 4, 5, 6Mpa, the pressure response of the inlet are shown as Figure 13-15. It can be seen that: (1) the inlet pressure is higher than the outlet set pressure due to the energy loss of the pipeline fluid. (2) When the pressure rising to 1 Mpa, the inlet pressure is higher than 1Mpa, which is due to the increase in pressure and the energy loss increases. (3) The pressure waveform is correct according with the characteristics of draining process of the plunger pump pressure oil. The data of the outlet pressure are shown as Figures 16, Figure 17 and Figure 18.

The harmonic vibration of the low frequency, especially the amplitude of the first order frequency vibration increases compared with the vibration caused by the inlet pressure. It is also clear that the overall vibration amplitude does not change much.

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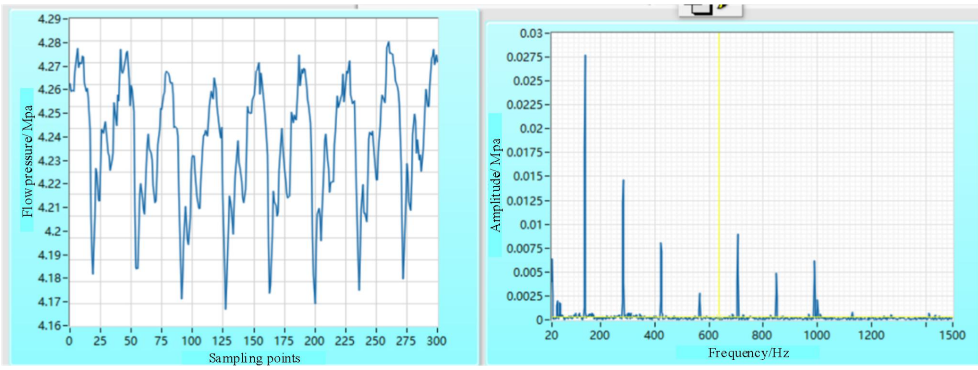
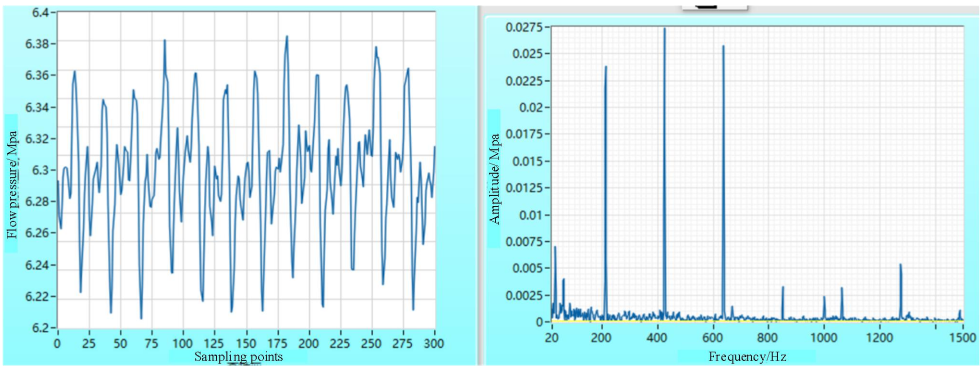


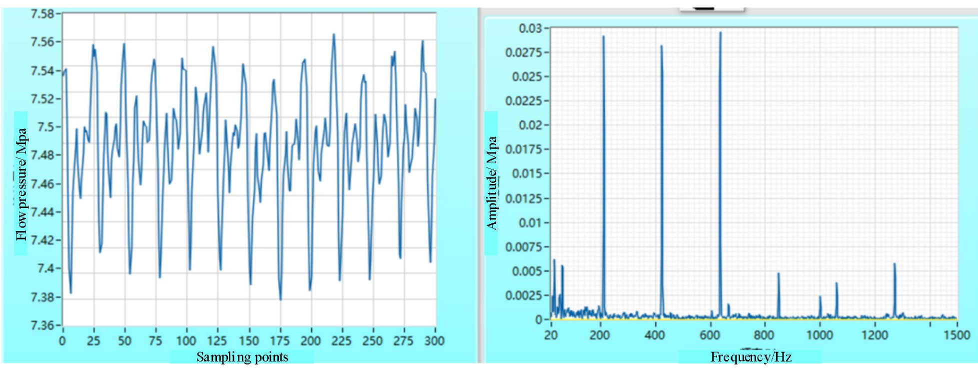
(a) Time domain (b) Frequency domain

Fig.13. Pressure response diagram at 4Mpa



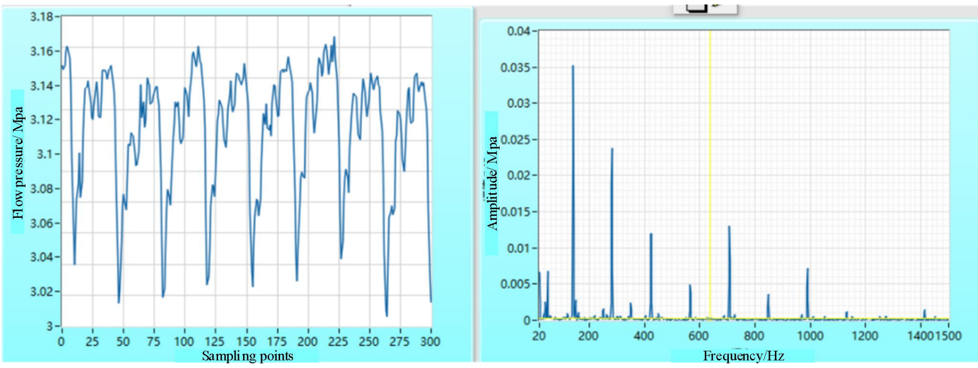
(a) Time domain (b) Frequency domain

Fig.14. Inlet pressure response diagram at 5Mpa



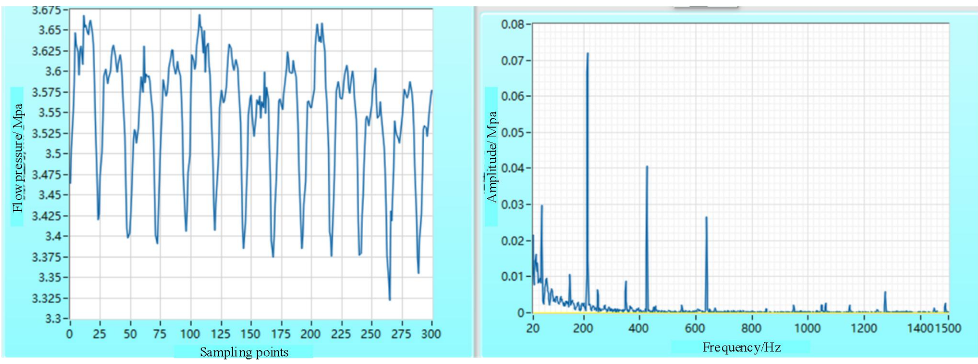
(a) Time domain (b) Frequency domain

Fig.15. Inlet pressure response diagram at 6Mpa



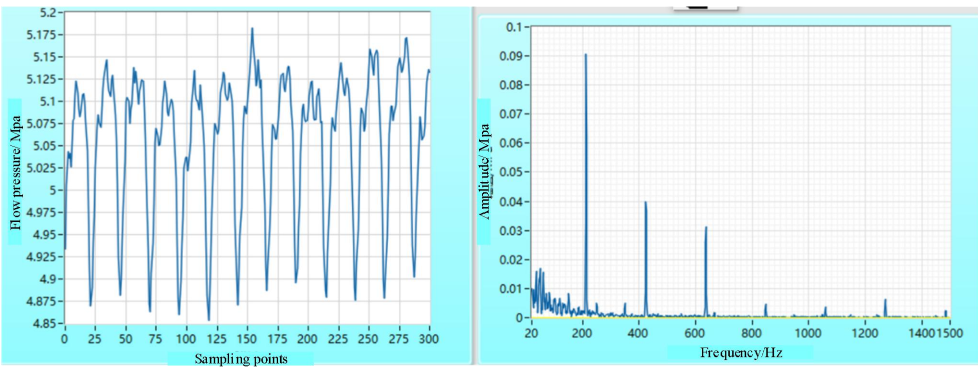
(a) Time domain (b) Frequency domain

Fig.16. Outlet pressure response diagram at 4Mpa



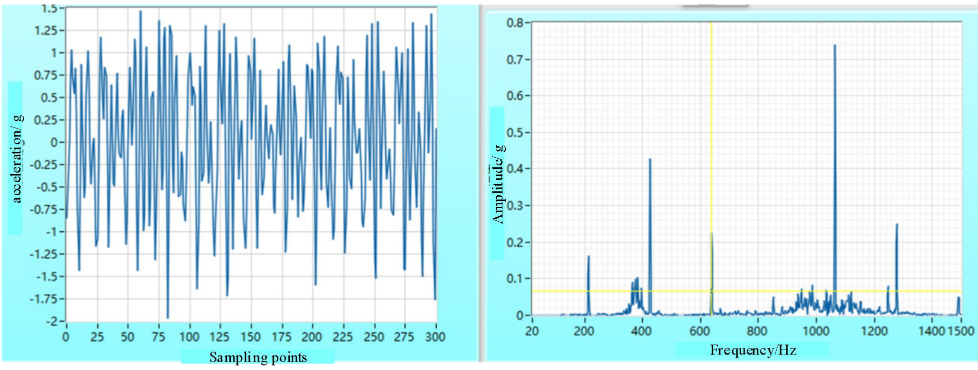
(a) Time domain (b) Frequency domain

Fig.17. Outlet pressure response diagram at 5Mpa



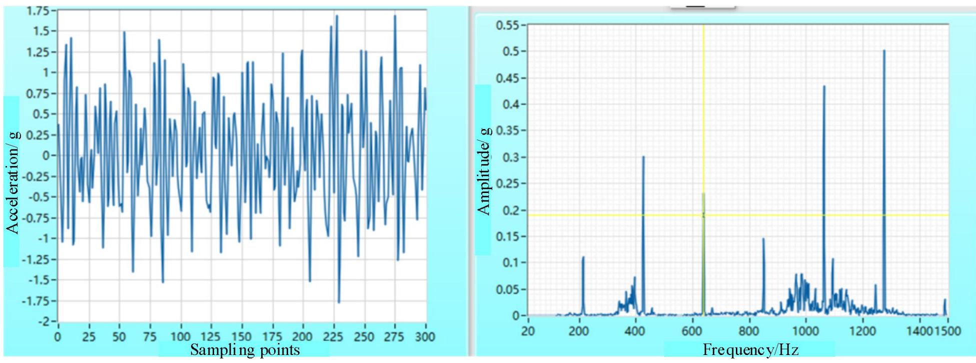
(a) Time domain (b) Frequency domain

Fig.18. Outlet pressure response diagram at 6Mpa



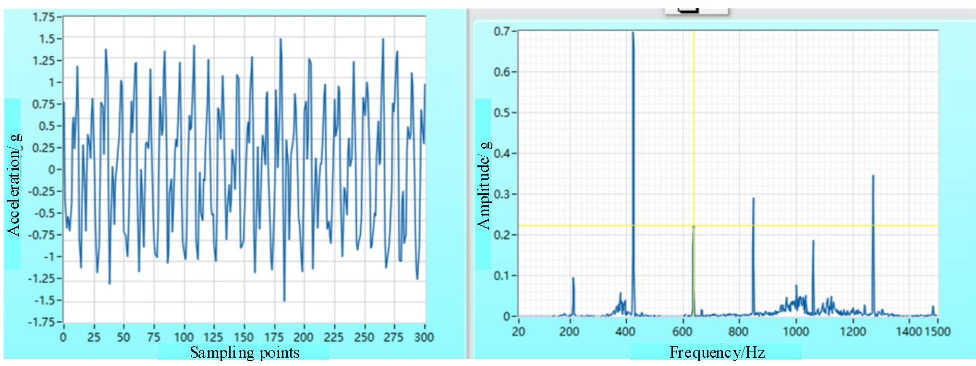
(a) Time domain (b) Frequency domain

Fig.19. Transverse acceleration response at 4Mpa



(a) Time domain (b) Frequency domain

Fig.20. Lateral acceleration response at 5Mpa



(a) Time domain (b) Frequency domain

Fig.21. Lateral acceleration response at 6Mpa

5 Conclusions

Based on the NI platform and LabVIEW software, the multi-physical parameters test system of the hydraulic pipeline is established. Five physical parameters including acceleration, pressure, strain, temperature and speed can be measured by the test system and real time display function can be realized. Three physical parameters of acceleration, pressure and strain related to vibration signals are mainly researched. The spectral peaks of frequency diagram and 3D waterfall map of the signals are displayed. The display range of the three-dimensional waterfall map can be adjusted to facilitate the observation of the local area. At the same time, the data of special time period can be saved.

During measuring process, the data can be real time displayed. The waveform of the signals, the spectrum diagram and the waterfall graph can be observed clearly. Through the experiment of changing pressure with fixed rotating speed and analysis of the acceleration signal, it can be seen that each frequency of every component is double frequency of the plunger pump. The calculation error is about 1%. Through the sweeping frequency experiment, it can be seen the frequency of the vibration signals measured by the acceleration sensors increases as the starting vibration of the pipeline, the it entering the resonance state. The vibration amplitude gets to peak value. From the three-dimensional waterfall diagram of the vibration signals, the peak value can be observed clearly corresponding to the resonant frequency.

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