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The Hydraulic Control Using LabVIEW for a Synthetic Rubber Spring Testing Machine

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Abstract: The application is a control movement of two hydraulic cylinder for a synchronize movement. The main purpose of this paper is to show a short programming code in LabVIEW to control the movement of two cylinders with an automatic control program using only analog inputs from the sensor of pressure and linear displacement sensor and the digital output from the hydraulic valves. This is designed for one of the test of this synthetic rubber spring testing machine.
Key words: rubber elasticity; multi layer rubber spring; stacked sequence structure
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Introduction

The synthetic rubber test machine is to test the rubber spring of the subway wagon. The practical use of this machine is to make a preventing maintenance so we can know with accuracy the spending life of the rubber spring. Every rubber spring is a subject of a cycle or working hours, after this period the testing of this spring rubber must do it according to specification of the manufacturer, the testing machine is designed to test 4 kinds of rubber springs; the one that is used for this test is called multi layer rubber spring. The main characteristic of this test, compared with the other rubber springs, is that this is the only one which combines the force of two cylinders: one vertical and one horizontal.

1 Structure Assembly

The structure assembly for the testing machine is very simple. The testing platform has an upper frame, mobile frame, lower frame, test piece vertical column of a chucking frame, chucking frame support upper of the working platform, hydraulic system is installed down to the working platform. The platform highest hydraulic pressure is 150 kN, and a simple mechanical structure only uses two vertical columns to hold it. At the same time the design is under the consideration of the rigid transversal measurement of the multi layer rubber spring elements. Moreover, there are different test pieces and the measurements are not the same.

The horizontal hydraulic cylinder is fixed into the frame structure. The altitude of the base can be modified according to the testing piece just changing the base support according to the test. The vertical pressure sensor is fixed at the head of the vertical cylinder. The movement of the vertical cylinder is always pushing down applying a compression force into the testing piece. The vertical sensor is installed at the bottom frame structure in a fixed position just parallel to the vertical columns. The vertical force sensor is installed at the base of the head of the vertical cylinder and also the horizontal displacement sensor is installed at the back of the horizontal cylinder right at the bottom of this(View Fig. 1).

During the elasticity test of a multi layer rubber spring, a horizontal force must be apply to 65 kN and then the horizontal cylinder must displace ±30 mm, during this process we acquire the analog signal from the force sensor of the horizontal cylinder, then we have to measure the constant K of the rubber spring for this reason using this formula $K=(F_1+F_2)/60$ (N/mm).

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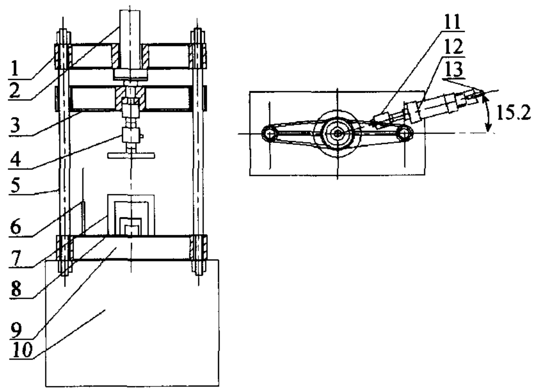

Fig. 1 General view of the testing machine

1—Upper frame; 2—Vertical cylinder; 3—Mobile frame; 4—Vertical force sensor; 5—Force column; 6—Vertical displacement sensor; 7—Test piece; 8—Tool plate; 9—Lower frame; 10—Assembly frame; 11—Horizontal force sensor; 12—Horizontal cylinder; 13—Horizontal displacement sensor

2 Pressure System

The pressure system principles can be seen as in the Fig 2. The system uses two hydraulic pump connected with an electrical motor, the hydraulic pumps never exceed the working pressure of 16 MPa, a flow of 6 mL/r and 16 mL/r. The pump station is designed with a pressure gauge meter, filter etc. The pumps working pressure (horizontal and vertical cylinder) is divided through four electromagnetic valves. The pump 1 is designed for three different working pressure (150, 100, 50 kN). Therefore for the high frequency of measurement test the speed of both hydraulic pumps can be adjusted using a valve. During the loading test the speed is about 1 mm/s, this is also during the unloading process. The speed can be adjusting around 2 mm/s; the system has two close valves these are for protecting the hydraulic pumps. The schematic of the hydraulic system can be appreciated in the Fig. 2 and the control and change of the electromagnetic valves can be seen in Tab. 1.

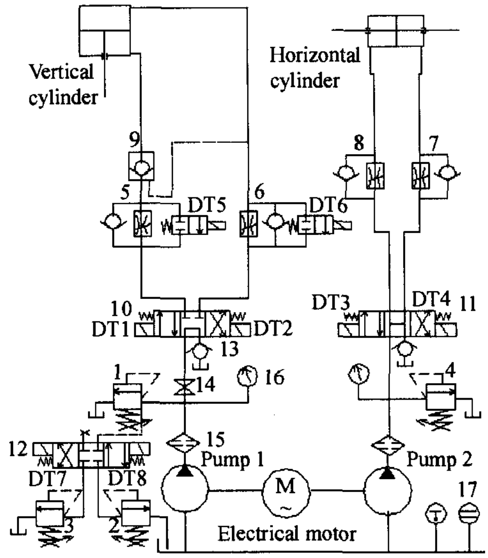

Fig. 2 Hydraulic pressure diagram

1,2,3,4—Pressure relief valve; 5,6—Electromagnetic commute valves; 7,8—One way re strictor; 9—Flow control one way valve; 10,11,12—Electromagnetic commute valves; 13—One way valve; 14—Gate valve; 15—Filter; 16—Pressure gauge; 17—Air filter

Tab. 1 Action chart of the hydraulic-system

	DT1	DT2	DT3	DT4	DT5	DT6	DT7	DT8
Standard state								
Main cylinder fast advanced	◇					◇		
Main cylinder slow advanced	◇							
Main cylinder slow return		◇						
Main cylinder fast return		◇			◇			
Horizontal cylinder left advanced				◇				
Horizontal cylinder right advanced			◇					
Main cylinder hydraulic pressure 1								
Main cylinder hydraulic pressure 2							◇	
Main cylinder hydraulic pressure 3								◇

3 Acquisition Card and Control Drivers

For the control and acquisition of data we use two different cards: one analog card to collect the signal from the sensors and the other digital card to control the on-off valves. Both cards are advantech cards, these cards are made in Taiwan and they are also controllable using LabVIEW, the drivers for LabVIEW must be downloading from the Website of Advantechl Company. The analog card is the PCL 818L 16 single-ended or 8 differential analog inputs, 40 kHz, 12-bit A/D converter (conversion time 25 μs). Programmable gain for each input channel (up to 8) Automatic channel/gain scanning with DMA. The Digital I/O card is PCL-730 which has 32 isolated DIO channels (16 inputs and 16 outputs), the hardware structure you can appreciate in Fig. 3.

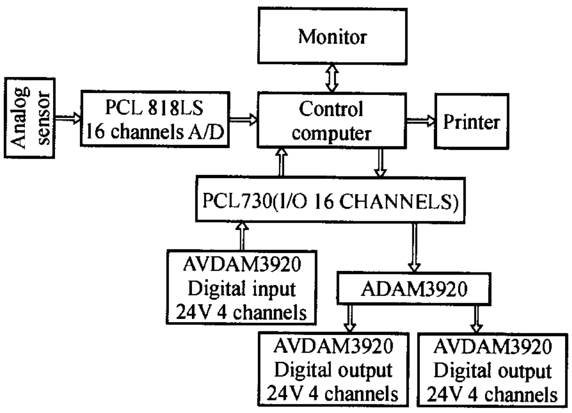

Fig. 3 The hardware system structure

4 Programming of the Control Program

Once we install the drivers for the advantech cards the program can start. The configuration of the program is a basic control using LabVIEW as it shows in Fig. 4.

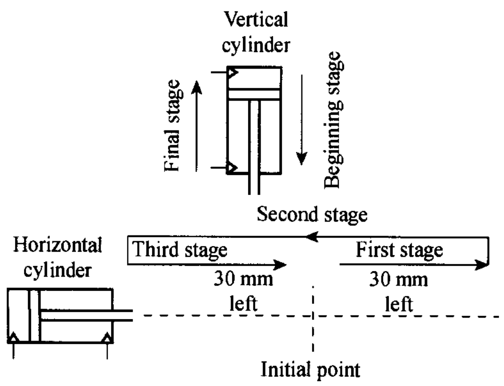

Fig. 4 View of the control process of the cylinders

At the beginning stage the vertical cylinder compresses the rubber spring until it senses a force of 65 kN then horizontal cylinder must start moving +30 mm to the right and then return to the left −60 mm and then move to the right +30 mm and stop, and the vertical cylinder returns to its original point (view Fig. 4). During this combination process one of the difficulties is the control movement because this movement must be synchronized to avoid both cylinders colliding. In this case we are going to show only the control for the cylinders because the full control of this program is too extended to show it in this report also we are only going to show the back panel program to control this test. This LabVIEW program is mainly designed by using the element called stacked sequence structure which consists of one or more sub diagrams, or frames, that execute sequentially. Use the stacked sequence structure to ensure a sub diagram executes before or after another sub diagram.

4.1 Beginning Stage

As you can see in Fig. 5, at the first stage when the vertical cylinder is coming down until the vertical force sensor acquire 65 kN of force against the rubber spring then the cylinder stops and stays in this position until the test is completed(See also Fig. 4).

4.2 First Stage

For the control of the horizontal cylinder, first we have to acquire the initial position using the horizontal displacement sensor, and then we can mark our initial point and base on this initial point and can make our displacement and control of the cylinder counting +30 mm (View Fig. 6).

4.3 Second Stage

During the second stage the return of the horizontal cylinder must extend −60 mm to the left and then stop, during this process we must acquire the measurement of the force that the cylinder exerts over the rubber spring(See Fig. 7).

4.4 Third Stage

In the third stage, the cylinder must return +30 mm to the right and then stop to the original point (first stage)(See Fig. 8).

4.5 Final Stage

Once the horizontal cylinder has returned to the original point (First Stage) and the program has shut off all the valves of the horizontal cylinder and then the vertical cylinder must start working. In this case, the vertical cylinder uses the vertical displacement sensor to make the cylinder return the original point of work, but at the beginning because we need to control the force applied to the spring rubber we have to use the force sensor to do this (See Fig. 9).

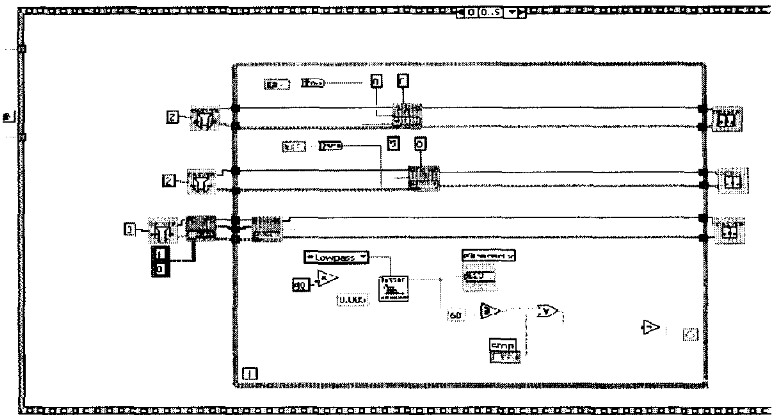

Fig. 5 Beginning stage of the vertical cylinder

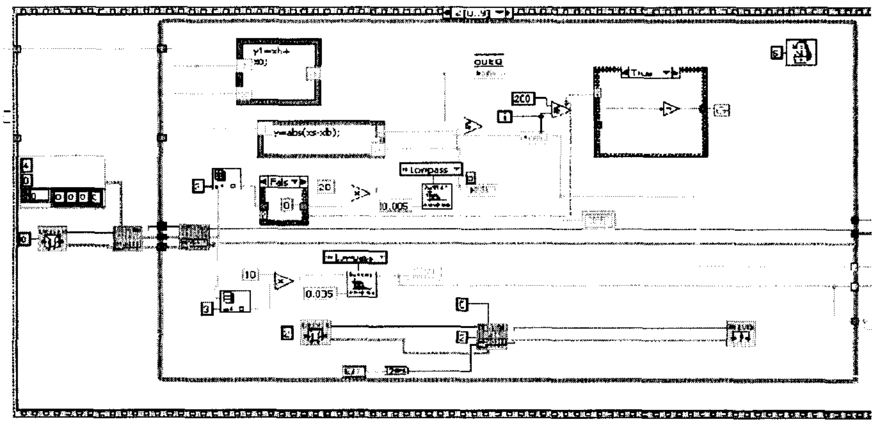

Fig. 6 First stage of the horizontal cylinder

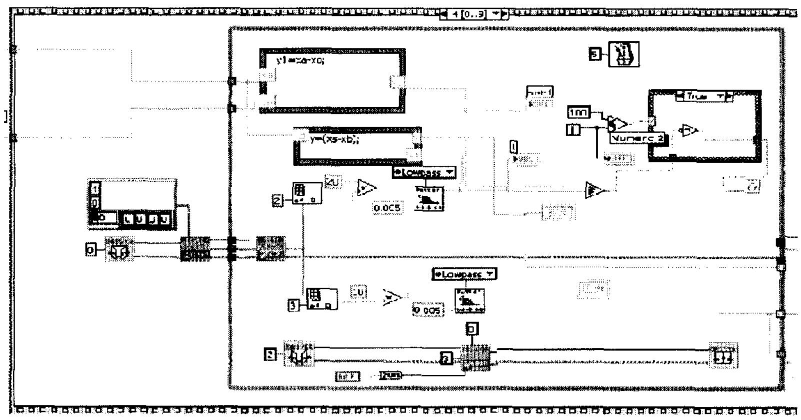

Fig. 7 Second stage of the horizontal cylinder

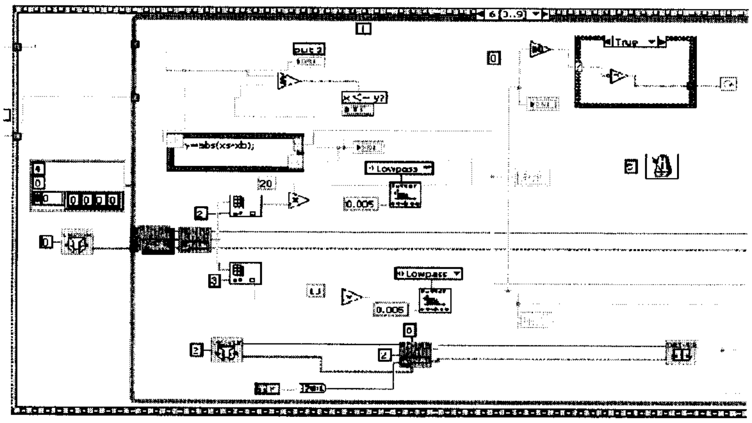

Fig. 8 Third stage of the horizontal cylinder

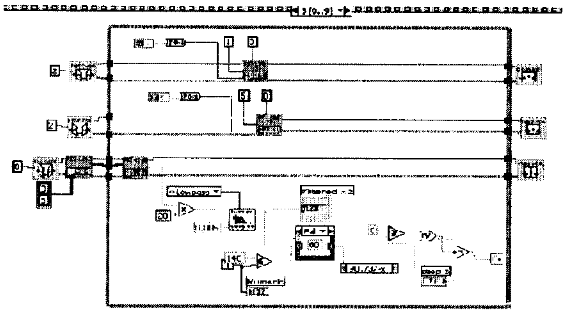

Fig. 9 Final stage of the vertical cylinder

The stacked sequence structure has many frames in order to make run a sequence we use 10 sequence during this program from 0 to 9; in this report we only show the principal stages, for the intern media stages are mainly to control the off of the valves of the last stage. This is because the valves that we are using are on-off valves and the retain memory of the last process, so we must careful when we programming by using the stacked sequence structure. For example, you can see Fig. 10, this show the last stage 9 which is when the vertical cylinder stops at the initial point.

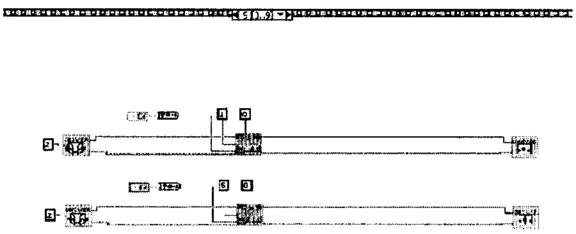

Fig. 10 Last frame of the vertical cylinder

The signals acquired from the horizontal displacement sensor and the horizontal force sensor are used to plot a curve of the elasticity of the rubber spring using, during this test we can measure the K^i constant of the rubber spring. This allow us to know the life cycle and also the condition of this rubber spring, to have a clear idea of this process we can see Fig. 11, as you see, F_y is the horizontal force signal (kN) and the S_y horizontal displacement signal (mm), F_1 and F_2 are the final forces acquired during the end of the measurement of the first and second stage. The final plot in the program can tell us the status of the multi layer rubber spring which you can see in Fig. 12.

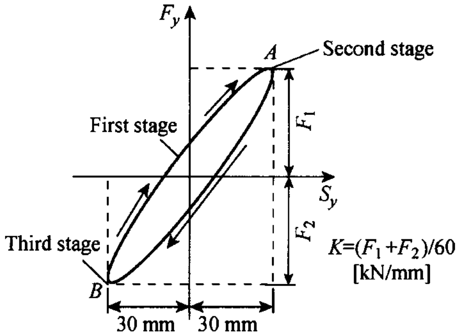

Fig. 11 Data processing of the rubber spring during the test

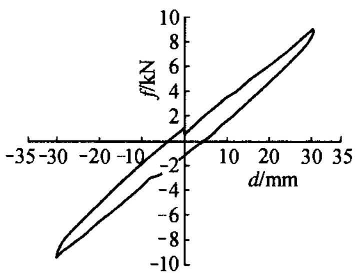

Fig. 12 Final plot of the rubber elasticity curve using the program data

5 Conclusion

LabVIEW is used to program the control of the cylinder. This is an easy and reliable software and without using coding programming to do this. The only issue that we must take care is to have the libraries for the acquisition card that we are going to use if these are not NI control cards.

The development of this machine helps us to make preventing maintenance. The elements of control are not difficult to acquire but the software could be a difficult step to do it, but using LabVIEW this step is a simple one. One of the advantages of LabVIEW is that the undergoing work can be seen in a visual way so this helps us to see and correct any mistake in the program without debugging the main code when we use Visual C++ or another programming language.

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