Control Method And Experimental Verification Of Pipeline Flow Fluctuation Generator

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Abstract

In the actual flow measurement process, flow fluctuations often propagate in the pipeline, which may cause large deviations in the flow measurement results. In order to systematically study the influence of different flow fluctuations on the measurement results of the flowmeter, it is necessary to simulate different controllable flow fluctuations in the pipeline. This paper designs different wave control methods for a vane flow fluctuation generator, and uses LabVIEW programming to control the motor to drive the butterfly valve to swing, forming controllable flow fluctuation of sine wave, frequency conversion sine wave and variable amplitude sine wave in the pipeline. Finally, based on the hot water flow standard facility of National Institute of Metrology（NIM）, a real flow experiment is designed to verify the control method of the fluctuation generator. Experimental results show that the proposed control method can control the flow fluctuation generator to generate controllable sine wave， frequency conversion wave and variable amplitude wave , and the flow fluctuation can be propagated along the pipeline upstream and downstream.

1. Introduction

Flow measurement is an important part of metrology science [1]. Flow measurement and testing technology has always played an important role in trade settlement, energy measurement, process control, environmental protection, medicine and health [2]. In order to ensure the quality of flow meters, flow standard facilitys with different media, different ranges and different precisions have been established in the metering system and each flowmeter manufacturer [3-4]. The flow stability of the facility reflects the degree of flow change with time. Due to the fluctuation of the power supply parameters of the power grid or the performance of the liquid pump itself, the change of the outlet pressure of the liquid pump [5] causes flow fluctuations and brings certain errors to the flow measurement. The flow stability of the facility largely depends on the stability of the pressure source [6]. How to solve the problem of pressure stabilization of the liquid flow calibration facility is a problem that has been studied and discussed at home and abroad in recent years [7].

Foreign scholars divide the fluid whose flow parameters change periodically into "oscillating flow" and "pulsating flow/pulsating flow" [8]. Oscillating flow is the fluid whose time-average velocity is zero, and pulsating flow is the fluid whose time-average velocity is not zero. The pulsating flow is usually formed by the superposition of oscillating flow and steady-state flow [9-11]. The main source of fluctuation in the flow standard facility is caused by the centrifugal pump. At the same time, the opening and closing of the valve, the design of the elbow in the pipeline or the sudden change of the diameter of the pipeline may bring different fluctuations in the process of flow measurement [12]. Once the pulsatile flow in the fluid is generated, it propagates in the fluid [13]. The frequency range of pulsating flow is very large, generally from a fraction of a hertz to several hundred hertz. Some have a natural frequency caused by a pump, and the pulsation frequency can be measured by changing the fluid pressure and flow rate [14]. However, there are still some random pulsations in the fluid, which are difficult to measure [15], but this pulsation frequency will cause a large error in the indication value of the flowmeter. Therefore, it is particularly important to conduct a systematic study on the influence of the flow meter by generating a controllable pulsating flow through the pulsating flow generator.

In this paper, a set of control methods is designed for a vane-type flow fluctuation generator developed by the NIM . The motor is programmed and controlled through LabVIEW. The motor controls the lower butterfly valve to swing through the coupling. Controlled frequency, amplitude and waveform flow fluctuations. Based on the hot water flow standard facility of the NIM, we designed a real-flow experiment to verify the control method of the fluctuation generator. The experimental results show that the control method can control the flow fluctuation generator to produce controllable frequency conversion, variable frequency The flow fluctuation of amplitude and variable waveform can be propagated along the upstream and downstream of the pipeline, which lays a foundation for the subsequent study of the influence of flow fluctuation on the measurement results of the flowmeter.

2.Control method of flow fluctuation generator

2.1 Introduction of flow fluctuation generator

The structure of the flow fluctuation generator is shown in the figure. It is mainly composed of a valve, a connecting shell, a transition plate, a motor, a connecting shaft, and a gland. The top of the facility is a controllable servo motor. The motor uses its own controller. , through the host computer to adjust the speed of the motor; the lower part of the motor is a sleeve, which plays the role of fixing and supporting the upper motor and connecting the lower facility; the inside of the sleeve is a rotating shaft, which is used to connect the motor output shaft and the butterfly valve stem, the rotating shaft It is directly connected with the output shaft of the motor and the valve stem of the butterfly valve by means of key connection, so that the connection method can reduce the loss caused by the transmission process. An angle mark is attached to the rotating shaft to judge the opening of the valve at this time; the butterfly valve is connected to the bottom of the butterfly valve stem, and the butterfly valve is controlled by the motor to swing back and forth in the pipeline, resulting in a flow fluctuation [16].

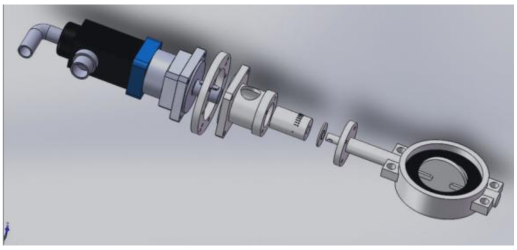

Figure 1: Structure diagram of fluctuation generator.

The system uses the LabVIEW host computer to control the fluctuation generator, and writes the parameters of the wave source to be generated into the servo driver through RS-232. The servo driver controls the motor through the CN2 line, and drives the motor to perform related commands. At the same time, in order to have a clear understanding of the type of the fluctuation source, the feedback pulse of the motor encoder is collected through the counter acquisition board, and the situation of the fluctuation source is reflected according to its information. The general motor control module is shown in Figure 2.

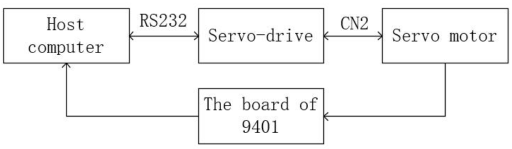

Figure 2: Overall Control Module Diagram.

The fluctuation generator is controlled by the LabVIEW host computer software. The fluctuation generator needs to be initialized before each control. After the fluctuation generator is started, the type of wave source to be generated can be selected, mainly including sine wave, frequency conversion wave, variable amplitude wave and motor positioning function. After selecting the required type of fluctuation source, run the fluctuation generator, and use the signal returned by the encoder to reflect the position of the fluctuation generator in real time and record the data, and use the collected data to verify the fluctuation situation and clarify the effect of the fluctuation. The control flow chart is shown in Figure 3.

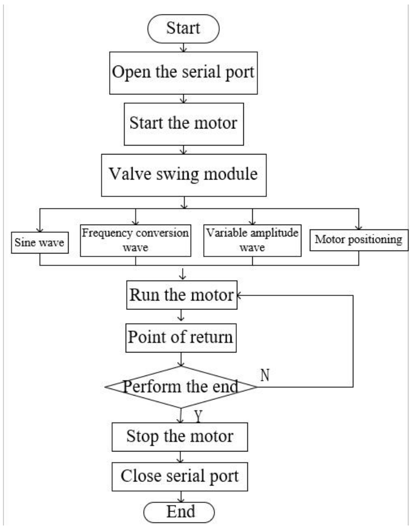

Figure 3: Control system flow chart.

2.2 Working principle of flow fluctuation generator

Since the flow fluctuation generator is mainly used to simulate the jitter of some valves, most of the fluctuations generated by the valve jitter are sinusoidal-like fluctuations, so it is necessary to use a water flow fluctuation generator to generate sinusoidal-like fluctuations. Therefore, the flow fluctuation generator needs to have fluctuation amplitude and fluctuation frequency to generate such sinusoidal-like fluctuations. The fluctuation range can be obtained by converting the number of pulses of the servo motor, and the fluctuation frequency can be obtained by converting the speed of the servo motor.

The relationship between the fluctuation amplitude of the flow fluctuation generator and the pulse number of the servo motor is:

$$\alpha = \frac{m}{500000} \times 360 \qquad (1)$$

In the equation, α is valve swing angle,unit is °;m is number of pulses. The number of pulses generated by one revolution of the servo motor is 1,280,000. Set the gear ratio to 128:10, then the number of pulses required for one rotation is 100,000. At the same time, due to the addition of a reducer with a reduction ratio of 1:5, the number of pulses required for the servo motor to actually rotate one circle is 500,000. In this way, the fluctuation range of the flow fluctuation generator can be obtained.

The relationship between the fluctuation frequency of the flow fluctuation generator and the speed of the servo motor is:

$$n = \frac{f \times 4\alpha \times 60}{360} \qquad (2)$$

In the equation, n is motor rotation speed,unit is r/min; f is valve swing frequency,unit is Hz; α is valve swing angle,unit is ° . It can be understood that when the flow fluctuation generator is swinging, its swing frequency is 1s to do several groups of actions. In a group of actions, the motor will go through three actions of forward rotation - reverse rotation - forward rotation and four swing angles, that is, forward rotation. Rotate-reverse back to the original position-reverse-reverse-forward and return to the original position, and then divide by 360° to convert to the number of revolutions the motor rotates per second. Since the internal speed of the servo motor is set to how many revolutions per minute, So multiply by 60 to get the motor rotation speed. In this way, the fluctuation frequency of the flow fluctuation generator can be obtained.

2.3 Flow fluctuation generator function

2.3.1 Motor positioning

The motor positioning is mainly used to control the opening of the butterfly valve. By swinging the motor forward or reverse to the specified position, the positioning of the butterfly valve is realized. After writing the amplitude and angle to be oscillated into the motor register through the LabVIEW host computer, run the motor to realize the positioning of the fluctuation generator. Its flow chart is shown in Figure 4.

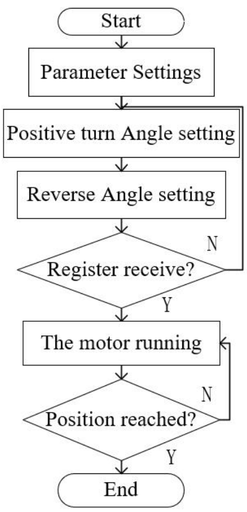

Figure 4: Flow chart of motor positioning.

2.3.2 Generation of sine wave

To control the generation of sine waves, we must first understand the PR program. This is the motor register. The PR program has a total of 64 registers. The operation of the motor is to execute 1, 2, 3... in sequence, and a certain register can be used as a jump function.

A sine wave means that the motor rotates forward-reverse-forward in sequence. Of course, it needs to rotate around a certain central axis. For example, if the amplitude is 3, that is forward rotation 3-reverse rotation 6-forward rotation 6-reverse rotation 6 - Forward rotation 6 cycles in turn, so 4 registers are required, the first forward rotation 3, the second reverse rotation 6, the third forward rotation 6, and the fourth loop jumps to the second register to realize the sine wave produce.

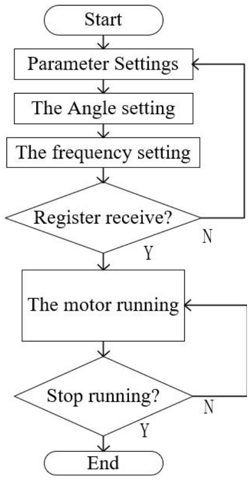

Figure 5: Flow chart of sine wave generation.

2.3.3 Generation of variable amplitude wave

The variable amplitude wave function is similar to the sine wave function, but the difference is that the amplitude and frequency of the sine wave are fixed, but the frequency of the variable amplitude wave is fixed, and the amplitude is different each time. Due to the characteristics of the motor, when executing the command in a certain register and continuing to write a new command to the register, the running command will be executed first and then the new command will be executed after the next run to the register, so As long as the motor finishes executing the command in the register, and writes a new command into the register, it can ensure that the command in the register is different each time it is executed. The sine wave amplitude value is generated using Equation (2), and the variable amplitude wave amplitude value is generated using random numbers. In order to make the motor rotate around the fixed axis, the angle of each forward rotation needs to be the angle value of the previous reverse rotation plus a new value. The forward rotation angle value of , and the angle of each reverse rotation is the angle of the previous forward rotation plus the new reverse rotation angle value, so that the motor can rotate around the fixed axis. At the same time, in order to make the forward and reverse rotation more obvious, it is necessary to set a limit for this random number, that is, the maximum amplitude and the minimum amplitude, so as to realize the variable amplitude wave function. The flow chart of its variable amplitude wave function is shown in Figure 6.

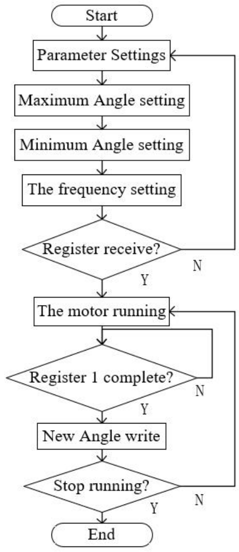

Figure 6: Flowchart of the variable amplitude wave function.

2.3.4 Generation of frequency conversion wave

The frequency conversion wave function is similar to the sine wave function, but the difference is that the amplitude and frequency of the sine wave are fixed, but the amplitude of the frequency conversion wave is fixed, and the frequency is different each time. The generation of sine wave frequency can be obtained by Equation (1), and the generation of frequency conversion wave frequency needs to be given by random numbers. Also using the characteristics of the motor, each time a command in a register is executed, a new frequency command is written into the register to ensure that the frequency is different each time. At the same time, since it takes a certain amount of time to write the command of the motor, the set value of the frequency should not be too high, otherwise, a new command will be generated that has not been written yet, and the motor has executed the last command, resulting in no frequency conversion function. That is, it is necessary to set an upper and lower limit for the frequency conversion to ensure that the frequency is different each time. The flow chart of its frequency conversion wave function is shown in Figure 7.

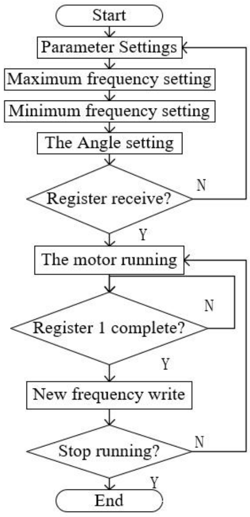

Figure 7: Flow chart of frequency conversion wave function.

3. Validation of control method

3.1 The experiment design

Validation experiments were designed to verify the controllability of the waveform generated by the flow fluctuation generator, which was carried out in the OP2 pipeline of the hot water flow standard facility of NIM. The inner diameter of the pipeline was 100mm, the flow range was 0.03-600 m^3 /h, and the maximum pipeline pressure was 0.4 Mpa. The schematic diagram of the test pipe section is shown in Figure 8. Figure 9 shows the overall pipe layout. Arrows in the figure indicate the positions of sensors and flowmeters.

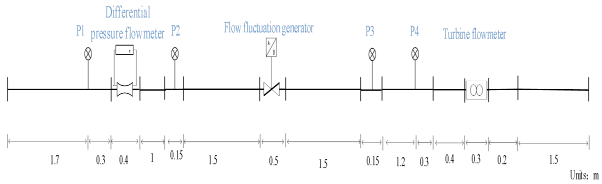

Figure 8: Schematic diagram of test pipeline installation.

Figure 9:Pipeline installation site map.

In the test pipeline, the flow fluctuation generator was installed in the middle position, and two pressure sensors are installed in the upstream and downstream of the flow fluctuation generator respectively. The controllability of the flow fluctuation generator can be verified by collecting the data of the pressure sensor.

3.2 Sine wave function verification

When a sinusoidal signal with a frequency of 1Hz and a amplitude of 10° needs to be generated, relevant parameters are written into the servo driver through the upper computer, and then the motor is driven to carry out relevant actions.

First verify the accuracy of amplitude writing. The pulse generated by the motor running one circle is 500000, so the pulse number generated by rotating 10° is 13889. The pulse number written by ASDA-Soft is indeed 13889, so the pulse value written is also correct, that is, the command written on the rotation angle of the motor is correct. Since the positioning function is needed to generate various waveforms, as long as the waveform generation function can be verified, the positioning function naturally has no problem.

When the butterfly valve opening is 60° and the flow is 50m^3/h, a signal with a frequency of 1Hz and an amplitude of 10° is generated through the fluctuation generator, the actual signal generated is biased. Taking the data value within any 1s returned by the motor encoder, it is found that the angle value of the forward direction is 69.576° , and the angle value of the reverse direction is 51.050° , which may be related to the direction and flow of water flow. The encoder return value is shown in Figure 10.At the same time, calculate the elapsed time from the maximum to the minimum of the motor position within 1s. The elapsed time is 0.488s, which is less than 0.5s, which is converted to the frequency value of 1.025Hz. At the same time, the pressure sensor was used to measure the wave generated in the pipeline, and it was found that its frequency value was 1.022Hz, so the frequency value of the generated sine wave was basically consistent with the measured value.The pressure sensor data spectrum is shown in Figure 11.The comparison between the set value and the actual value of the sine wave frequency is shown in Table 1.

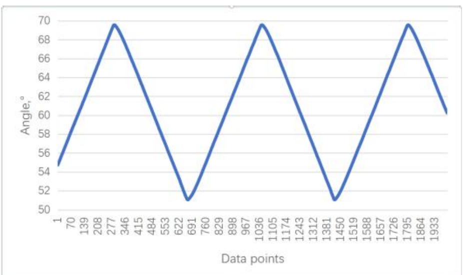

Figure 10: Encoder Return Value.

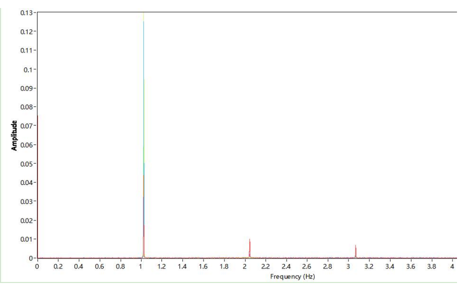

Figure 11: Pressure Sensor Measurements.

Table 1: Sine wave comparison table.

Comparison of parameters	Frequency /Hz	Forward Angle/°	Reverse Angle/°
Set value	1.000	10.000	10.000
Actual value	1.025	9.576	8.950

Analysis the reasons, servo motor in the process of continuous running, every time will experience a process of acceleration, uniform speed and slowdown, and in setting the motor speed is according to the time at a constant speed motor speed, the acceleration and deceleration is not that into consideration, the speed of the two time relative to the uniform section speed must be less than, at the same time, due to the design problem of the flow fluctuation generator, there will be a certain gap at the connection position, and water flow will also affect the speed of the motor, which may lead to the step length of the motor running less than 10° , and thus the frequency value will be slightly more than 1Hz. So the actual value will deviate from the set value.

3.3 Variable amplitude wave function verification

The initial frequency of a variable amplitude wave can be set and the maximum and minimum of its amplitude can be set. The reason for setting the minimum is to allow a certain amount of time to write the amplitude in real time. Figure 12 shows the pressure sensor amplitude waveform.

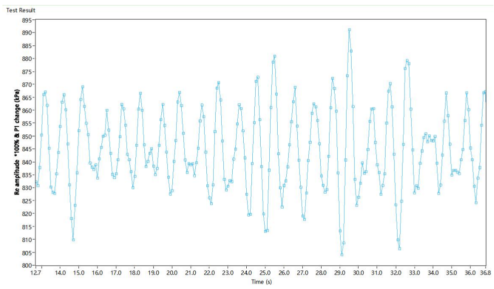

Figure 12: Pressure sensor waveform of variable amplitude wave.

3.4 Frequency conversion wave function verification

The maximum set frequency of frequency conversion wave is 5Hz, and the amplitude can be arbitrarily set. Through real-time collection of the information of the encoder, it can be seen that the amplitude changes slightly within a certain range, and there is a frequency change between the two waveforms.

As shown in Figure 13, the maximum forward amplitude of the data returned by the encoder is 4.69° and the maximum reverse amplitude is 4.10°. A piece of data that changes from the maximum value to the minimum value is randomly selected and its frequency is calculated as 2.5Hz, which meets the requirements within 5Hz.

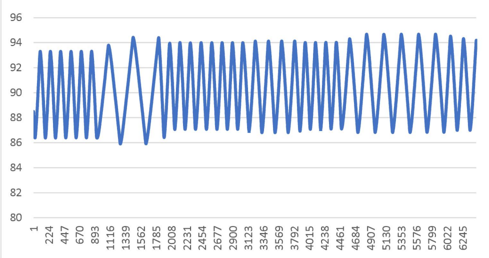

Figure 13: Frequency conversion wave encoder return value.

Table 2 shows the frequency conversion wave ratio table. Since it is an arbitrary value and its frequency is changing, it can only meet the setting of its frequency value less than 5Hz, so it cannot get specific value. The Angle value of positive turn and reverse turn will be smaller than the set value, which is similar to the phenomenon of sine wave and will not be described here.

Table 2: Frequency conversion wave comparison table.

Comparison of parameters	Frequency /Hz	Forward Angle/°	Reverse Angle/°
Set value	The maximum is 5	5.000	5.000
Actual value	Less than 5	4.690	4.100

4. Conclusion

In this paper, for a vane-type fluctuation generator, fluctuation control methods and LabVIEW program were designed to generate controllable frequency, amplitude, waveform of flow fluctuation. In order to verify the control method of flow fluctuation generator, a real flow experimental platform was built based on the hot water flow standard facility and flow fluctuation generator of NIM, and the real flow verification experiment was carried out. Experimental results show that the proposed control method can control the flow fluctuation generator to generate controllable flow fluctuations as sine wave ,frequency conversion sine wave and variable amplitude sine wave , which lays a foundation for the subsequent research on the influence of flow fluctuation on flowmeters.

Acknowledgement

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